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Interface Control Document Between Landsat 7 and the Landsat 7 Ground Network (LGN)

Original

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National Aeronautics and
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Goddard Space Flight Center
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Preface

This document is under the configuration management of the Landsat 7 Project, Code 430 Configuration Control Board (CCB) until 90 days after launch. At that time responsibility for this document is transferred to the NOAA Mission Management Office.

Until launch + 90 days, Configuration Change Requests (CCRs) to this document shall be submitted to the Project CCB, along with supportive material justifying the proposed change. Changes to this document shall be made by document change notice (DCN) or by complete revision.

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Change Information Page

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Section 1. Introduction

1.1 Purpose and Scope

This Interface Control Document (ICD) defines interfaces among the Landsat 7 (L7) spacecraft, the Landsat Mission Operations Center (MOC) at the Goddard Spaceflight Center (GSFC), and the facilities comprising the Landsat Ground Network (LGN). Both Radio Frequency (RF) interfaces between the L7 spacecraft and ground stations and the interfacility interfaces between ground elements are covered. The LGN consists of Wallops Flight Facility resources supporting L7, which are collectively referred to as the Wallops Ground System (WGS) in this document, and portions of the Data Handling Facility at the Earth Resources Observations System (EROS) Data Center.

The EROS Data Center (EDC) is a U.S. Geological Survey facility located in Sioux Falls, South Dakota that hosts a variety of systems and functions relating to the Earth sciences. The Data Handling Facility (DHF) is a subset of the EDC that supports L7. The DHF consists of hardware/software systems and the people and procedures that manage and operate those systems. The primary component of the DHF that is part of the LGN is the Landsat Ground Station (LGS). Additionally, specific DHF administrative functions are part of the LGN in that they directly support the recovery and processing of L7 data. Both the LGS and the DHF have interfaces which are described in this ICD.

The WGS consists of the Alaska Ground Station in Poker Flats, Alaska, the Svalbard Ground Station located on Spitzbergen Island, Norway, and the Wallops Orbital Tracking Station (WPS) and the Wallops Orbital Tracking Information System (WOTIS) at Wallops Island, Virginia. All of the interfaces among these facilities, the L7 spacecraft, and other elements of the LGN are included in this ICD.

While the MOC is a hardware/software system that is used to plan and conduct spacecraft and payload operations, certain activities are initiated and/or accomplished by personnel. For these cases, the Flight Operations Team (FOT) is identified as an active interface participant, however, this ICD is geared toward defining the MOC interfaces.

Figure 1-1 and the accompanying Table 1-1 illustrate the scope of this document and provide a reference to the pertinent section for each interface.

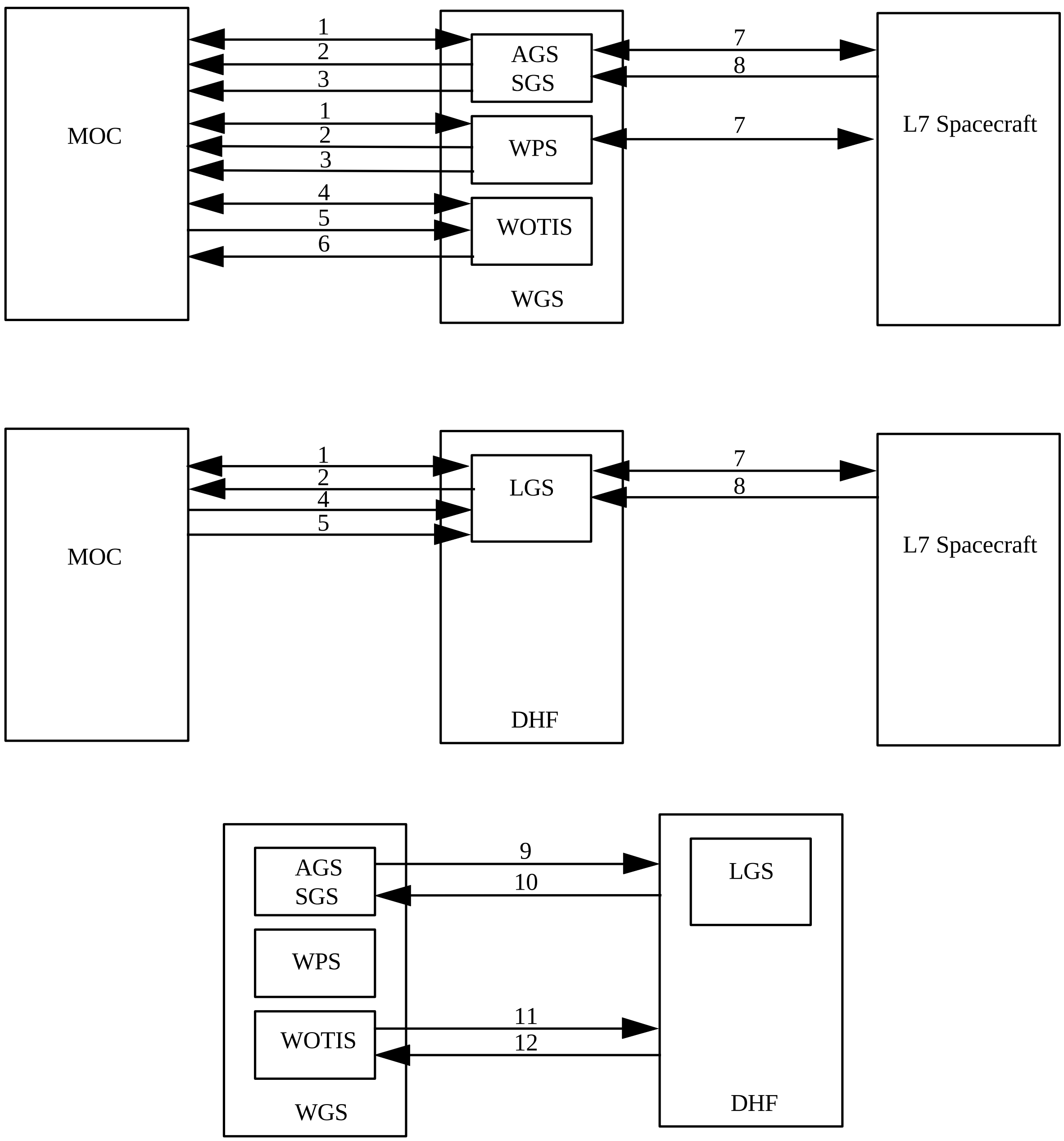


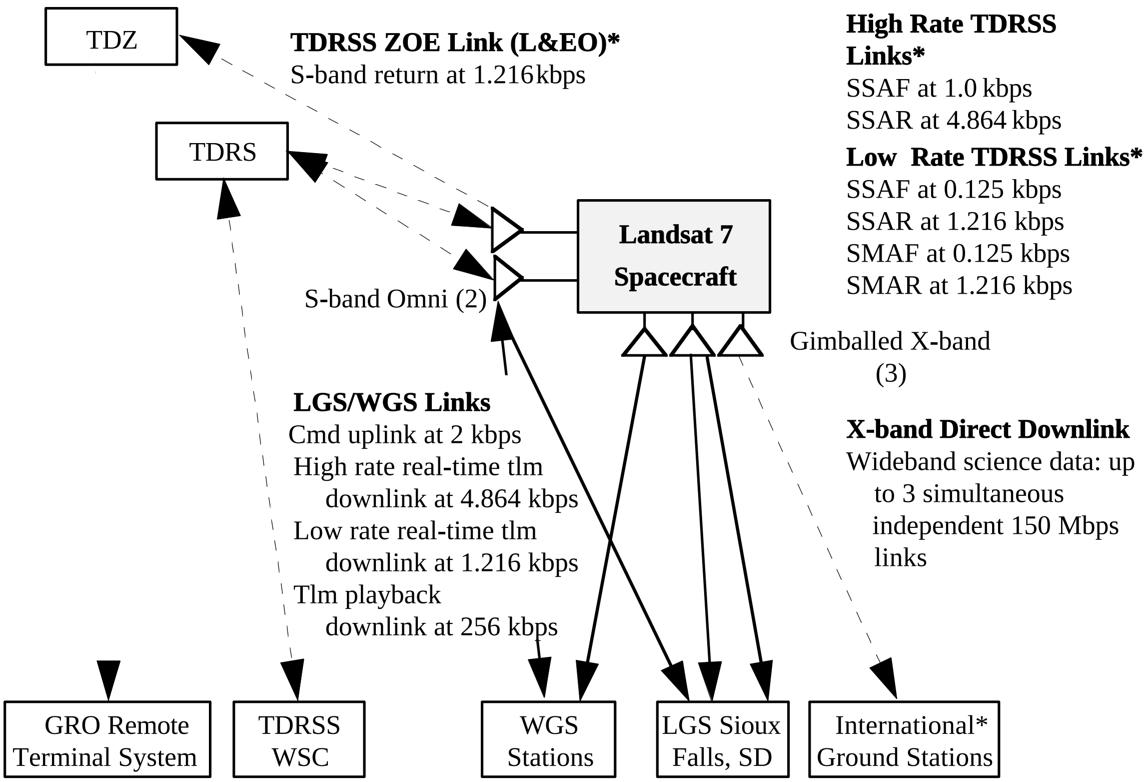
Figure 1-1. L7-LGN ICD Scope

Table 1-1. L7-LGN ICD Scope

Item Number	Interface Type	ICD Section
1	Command and Telemetry IPDUs	6
2	Tracking Data	3, 6
3	Status Data	6
4	Schedules	6
5	Acquisition Data	6
6	Downlink Summary Reports	6
7	S-Band Command and Telemetry Data	3, 5
8	X-Band Science Data	3, 4
9	Science Data Tapes	6
10	Recycled Tapes	6
11	Tape Shipment Reports	6
12	Tape Acknowledgment Reports	6

1.2 Landsat 7 System Overview

The L7 System is a satellite system used to perform high resolution multispectral imaging of the Earth from a sun-synchronous, near-polar orbit. The L7 spacecraft is operated from the L7 MOC at the GSFC, in Greenbelt, Maryland. As shown in Figure 1-2, Landsat 7 supports communications interfaces with the Space Network (SN), LGN, and International Ground Stations (IGSs) to accomplish mission goals. The MOC receives narrowband telemetry data from the spacecraft and sends commands to the spacecraft via the LGN and the SN. Wideband science data are downlinked to the LGN and to IGSs. Data collected at the LGN sites are provided to the primary data processing facility, the L7 Processing System (LPS), which is part of the DHF. Data collected by the IGSs are processed and maintained at these facilities. The Earth Observation System (EOS) Data Archive and Access Center (DAAC) located at the EDC provides the capabilities for users to access all of the processed L7 data, including IGS holdings. Uses for L7 data include a variety of scientific, military, and commercial applications involving global change research, national security, and civil and commercial research and planning.



*IGS and TDRSS Links are not controlled by this ICD and are shown for information purposes only.

Figure 1-2. L7 RF Communications Links

1.3 Interface Responsibilities

NASA has the responsibility for the development, implementation and launch of the L7 spacecraft and the analogous responsibilities for the ground system. Various groups within NASA participate and manage the development of these mission segments and therefore have defined and developed the interfaces described herein. The L7 spacecraft is the responsibility of the Landsat Project Office (LPO), Code 430, at GSFC. The implementation of the MOC and LGS and their respective interfaces are the responsibility of the MO&DSD, also at GSFC. DHF interfaces are the responsibility of the USGS. The Suborbital Projects and Operations Directorate (SPOD), Code 800, at Wallops Flight Facility at Wallops Island, Virginia, is responsible for the WGS. After launch + 90 days, responsibility for the spacecraft and the mission transfer to the National Oceanographic and Atmospheric Administration (NOAA).

1.4 Document Organization

a. Section 1 explains the purpose of this ICD and provides a system overview.

b. Section 2 lists applicable and reference documents.

c. Section 3 provides RF communications and tracking requirements.

d. Section 4 contains X-Band link characteristics.

e. Section 5 contains S-Band link characteristics.

f. Section 6 defines the inter-facility data flows necessary for commands, telemetry, science data, tracking, scheduling, and status reporting.

Section 2. Documents

2.1 Applicable Documents

The following documents are applicable to the L7 spacecraft. In the event of conflict between this ICD and the documents listed below, the documents below shall govern.

a.	430-L-0002-A	L7 System Specification, Current issue.
b.	430-11-01-003-0	L7 Detailed Mission Requirements, 25 March 1996.

2.2 Reference Documents

The following documents are reference documents applicable to the RF and ground system interfaces being controlled. These documents do not form a part of this ICD and are not controlled by their reference herein. In the event of a conflict between this ICD and documents listed below, the ICD shall govern.

a.	MOSDD-L7-MOP.000	L7 Mission Operations Concept Document, July 1996.
b.	531-FPR-GN/L7	L7 Ground Station (LGS) Functional and Performance Specification, September 1996.
c.	531-OCD-GS/L7	L7 Ground Station (LGS) Operations Concept, Current issue.
d.	511-4ICD/0296	L7 Mission Operations Center (MOC) to L7 Ground Station (LGS) Interface Control Document, August 1996.
e.	430-11-06-006-0	L7/Flight Dynamics Facility Interface Control Document, Revision 0, July 1996.
f.	STD No. 724	Tracking and Acquisition Handbook for the Space Flight Tracking and Data Network, Revision 5, March 1990.

2.3 Other Related Documents

The following documents are listed for the convenience of the user. These documents do not form a part of this ICD and are not controlled by their reference herein. In the event of a conflict between this ICD and the documents listed, the ICD shall govern.

a.	PS23007605	L7 System Space Segment Satellite Specification, 12 May 1994.
b.	PS23007659B	L7 System Critical Item Development Specification for the L7 Space Vehicle S-Band Transponder, Revision B, February 1995.

c.	PS23007916	L7 System Prime Item Specification for the Communications Subsystem on the L7 Space Segment Satellite, Revision C, August 1995.
d.	CCSDS 101.0-B-3	Recommendations for Telemetry Channel Coding, May 1992.
e.	CCSDS 102.0-B-4	Recommendations for Packet Telemetry, November 1995.
f.	CCSDS 201.0-B-2	Recommendations for Telecommand, Part 1, Channel Service, November 1995.
g.	CCSDS 202.0-B-2	Recommendations for Telecommand, Part 2, Data Routing Service, November 1992.
h.	CCSDS 203.0-B-1	Recommendations for Telecommand, Part 3, Data Management Service, January 1987.
i.	CCSDS 701.0-B-1	Recommendations for Advanced Orbiting Systems, Networks and Data Links, October 1989.

NOTE

Source for CCSDS Documents: CCSDS Secretariat Communications and Data Systems Div. (Code-TS) National Aeronautics and Space Administration.

Section 3. Communications and Tracking Requirements

3.1 General

3.1.1 Interface RF Links

This section specifies the RF functional and performance requirements for the following RF communications links:

a. L7-to-LGS/AGS/SGS X-Band Downlinks

   1. 150 Mbps X-Band Direct Downlink
   2. 150 Mbps X-Band Direct Downlink
   3. 150 Mbps X-Band Direct Downlink

b. LGS/AGS/SG/WPS-to-L7 S-Band Uplink

   1. 2.0 Kbps S-Band Uplink Service

c. L7-to-LGS/AGS/SGS/WPS S-Band Downlink

   1. 4.864 Kbps S-Band Downlink Service
   2. 1.216 Kbps S-Band Downlink Service
   3. 4.864/256 Kbps S-Band Downlink Service
   4. 1.216/256 Kbps S-Band Downlink Service

3.1.2 Interface Functional Capabilities

The RF communications interface functional and performance capabilities will be provided as specified during the following project phases:

a. RF Compatibility Testing. Testing to be completed to LGS/AGS/SGS/WPS.

b. Launch and Ascent. Launch and Ascent phase includes nadir and zenith S-Band Transponder (SBT) power on following Payload Fairing (PLF) jettison. Allows for monitoring spacecraft while attached to the Launch Vehicle and solar array deployment and slewing following separation from launch vehicle.

c. Operations Initialization and Checkout. Full X-Band and S-Band communications operational.

d. Early Orbit/Contingency Operations. Full X-Band and S-Band communications capability.

e. Mission Operations. Full X-Band and S-Band communications capability.

3.2 Interface Functional Requirements

3.2.1 General

a. Paragraphs 3.2.2 and 3.2.3 describe the Communications and Tracking (C&T) functional requirements which exist between the L7 spacecraft and the LGS/AGS/SGS/WPS. The data rates specified include all applicable Consultative Committee for Space Data Systems (CCSDS) protocol overheads.

b. The L7 spacecraft antenna complement is comprised of two transmit/receive S-Band omni antennas and three transmit-only Gimballed X-Band Antennas (GXAs). One of the omni antennas is zenith facing and the other nadir facing. The omni antennas are left-hand circularly polarized (LHCP) and are configured to provide at least 80 percent S-Band spherical coverage on receive and commandable hemispherical/spherical coverage on transmit. The GXAs are right-hand circularly polarized (RHCP) and are nadir facing and steerable to +/- 67.0 degrees in the cross-track and along track directions. The GXAs are controlled by the X-Band Gimbal Drive Electronics (GDE) and the spacecraft's flight software.

c. The spacecraft has four X-Band transmitters which support transmission of wideband science data. The X-Band transmitters are capable of being configured to support a wide range of downlink options for transmission of wideband data to the LGS/AGS/SGS and to IGSs. The spacecraft supports transmitting three 150 Mbps downlinks to one site and one 150 Mbps downlink to another site at beginning of life. The spacecraft is capable of transmitting two 150 Mbps X-Band downlinks to one ground site and a separate 150 Mbps downlink to another site at end of life. The spacecraft is also capable of transmitting separate downlinks to each of three geographically separated ground sites at beginning of life.

d. The spacecraft has two S-Band transponders that operate continuously in the receive mode. The receivers in the L7 S-Band transponders simultaneously search for TDRSS pseudo-random noise (PN) code correlation and Spaceflight Tracking and Data Network (STDN) continuous wave (CW) signals greater than the detection threshold. Upon acquisition of one command signal type, the other mode is inhibited until loss of the initial signal and subsequent return to search mode occurs.

e. The L7 S-Band transponder transmits telemetry as commanded in either the TDRSS or STDN mode. TDRSS mode is commanded when telemetry is to be transmitted via the SN. STDN mode is commanded when telemetry is to be transmitted to a LGS/AGS/SGS/WPS station.

3.2.2 L7-LGS/AGS/SGS X-Band Links

The L7 spacecraft to LGS/AGS/SGS X-Band communications links provide the following functional capabilities when an RF line-of-sight exists between the spacecraft and the LGS/AGS/SGS, and the ground antenna local elevation angle is greater than or equal to 5 degrees.

3.2.2.1 Science Data

The LGS/AGS/SGS shall provide for the reception of digital science data from the spacecraft using the X-Band downlink service. Science data is ETM+ image data and payload correction data. It can be downlinked in real-time and/or from the Solid State Recorder (SSR). Support is dependent upon an RF line-of-sight and a ground antenna local elevation angle greater than or equal to 5 degrees. Each wideband science data link and data rate (including CCSDS protocol overhead) is as follows:

150.0 Mbps: Real-time ETM+ data or recorded ETM+ data from the SSR using X-Band service via the GXA downlink signal path.

3.2.3 L7-LGS/AGS/SGS/WPS S-Band Links

The L7 spacecraft-to-LGS/AGS/SGS/WPS S-Band communications links provide the following functional capabilities when an RF line-of-sight exists between the spacecraft and the LGS/AGS/SGS/WPS and the ground antenna local elevation angle is greater than or equal to 5 degrees. Upon acquisition of a STDN mode CW signal, the spacecraft receives and processes commands in the STDN mode. The spacecraft transmits telemetry in the STDN mode upon receiving a STDN mode signal when Auto-On capability is enabled or when commanded to do so.

3.2.3.1 Commands

The LGS/AGS/SGS/WPS shall transmit digital command data to the L7 spacecraft using the S-Band uplink service. The uplink command data rate (including CCSDS overhead) shall be as follows:

2.0 Kbps: Real-time and stored commands using S-Band uplink service.

3.2.3.2 Telemetry

The LGS/AGS/SGS/WPS shall receive digital telemetry data from the L7 spacecraft using the S-Band downlink service. The downlink telemetry data rates (including CCSDS overhead) shall be as follows:

a. 4.864 Kbps: High-rate real-time telemetry data using S-Band downlink service.

b. 1.216 Kbps: Low-rate real-time telemetry using S-Band downlink service.

c. 256.0 Kbps: Playback telemetry from the Solid State Recorder (SSR) using S-Band downlink service.

3.2.3.3 Doppler Tracking

The LGS/AGS/SGS/WPS shall generate two-way Doppler tracking data using the downlink S-Band RF carrier from the spacecraft. The downlink carrier will be coherently locked by the L7 S-Band transponder to the uplink carrier. The spacecraft's transmit carrier frequency will be related to the received carrier frequency by the ratio 240/221. The LGS/AGS/SGS/WPS shall also generate one-way Doppler tracking data, that is derived from the L7 S-Band RF carrier, to support characterization of oscillator drift in the L7 transmitter.

3.3 Command and Telemetry Link Performance Characteristics

3.3.1 General

3.3.1.1 RF Link Performance Requirements

a. The following paragraphs define the RF link performance requirements for each command and telemetry functional capability described in paragraph 3.2.

b. Link calculations demonstrating the RF link performance requirements within this section through the L7 and LGS/AGS/SGS/WPS communications system parameters specified in Sections 4 and 5 are provided in Appendix A as supporting information.

3.3.2 Science Data Channel

The maximum return link bit error rate (BER) for the digital science data (X-Band link only) shall be 10^{-5}, referenced to the output of the LGS ground terminal (i.e., the LGS matrix switch) when the return link signal meets all the X-Band requirements of paragraphs 4.4.1.2 and 4.4.1.3. With BCH error correction decoding at the Landsat Processing System (LPS) in Sioux Falls, the effective output science data BER will be 10^{-6}.

3.3.3 Command Channel Via LGS/AGS/SGS/WPS

The maximum uplink BER for the detected digital data in the spacecraft command channel shall be 10^{-6}, referenced to the output of the spacecraft's differential decoder, when the uplink signal meets the requirements specified in paragraph 5.4.2.2.

3.3.4 Telemetry Channel Via LGS/AGS/SGS/WPS

The maximum downlink information bit error rate BER for the detected digital data in the telemetry channel shall be 10^{-5}, referenced to the output of the bit synchronizer, when the downlink signal meets the requirements specified in paragraph 5.4.2.3. The BER after Reed-Solomon decoding at the receiving ground station will be 10^{-7}.

3.3.5 Doppler Tracking Via LGS/AGS/SGS/WPS

The strong signal instrumental Doppler noise, at the LGS/AGS/SGS /WPS, is 0.01 Hz at the 10 sample per second rate for the station's Doppler Measurement System (DMS).

3.4 Communication Link Modes

L7 spacecraft to LGS/AGS/SGS/WPS communication link modes shall be as defined in Tables 3-1, 3-2a and 3-2b.

Table 3-1. L7 X-Band Downlink Modes Via LGS/AGS/SGS

Mode	Link Number	Service	L7 Antenna (Polarization)	Data Rate (Bps) I	Q	Mod.	Freq MHz	Purpose
Low Frequency	8A	Downlink	GXA (RHC)	75 M *	75 M *	AQPSK	8082.5	Real-Time ETM+Data/SSR Playback Data
Mid Frequency	8B	Downlink	GXA (RHC)	75 M *	75 M *	AQPSK	8212.5	Real-Time ETM+Data/SSR Playback Data
High Frequency	8C	Downlink	GXA (RHC)	75 M *	75 M *	AQPSK	8342.5	Real-Time ETM+Data/SSR Playback Data

* Same Type Data (Real-Time ETM+ OR SSR Playback) Downlinked On I And Q Channel

Table 3-2a. L7 S-Band Uplink Mode Via LGS/AGS/SGS/WPS

Mode	Link Number	Service	Data Rate (BPS) Subcarrier	Carrier	L7 Antenna (Polarization)	Purpose
High Rate	9	Uplink	2.0K	N/A	S-Band Omni (LHC)	Real-Time Commands, Stored Command Loads, Memory Loads, And Tracking

Table 3-2b. L7 S-Band Downlink Modes Via LGS/AGS/SGS/WPS

Mode	Link Numbe r	Service	L7 Antenna (Polarization)	Data Rate (Bps) Subcarrier	Carrier	Mod.	Tracking	Purpose
High Rate Real-Time	10A	Downlink	Omni (LHC)	4.864K	N/A	**	Doppler*	Real-Time Telemetry, Tracking
Low Rate Real-Time	10B	Downlink	Omni (LHC)	1.216K	N/A	**	Doppler*	Real-Time Telemetry Tracking
High Rate Real-Time/ Playback	10C	Downlink	Omni (LHC)	4.864K	256.0K	**	Doppler*	Real-Time Telemetry, Tracking; Recorded Telemetry
Low Rate Real-Time/ Playback	10D	Downlink	Omni (LHC)	1.216K	256.0K	**	Doppler*	Real-Time Telemetry, Tracking; Recorded Telemetry

* Two-Way Coherent Doppler Tracking
** PSK on subcarrier and PM on carrier

Section 4. X-Band Link Interface Characteristics

4.1 Purpose

This section describes the functional design of the LGS/AGS/SGS X-Band links identified in Section 3 using illustrative end-to-end functional configuration descriptions. Pertinent spacecraft and LGS/AGS/SGS communications signal designs and system performance requirements are also provided.

4.2 Link Functional Design

4.2.1 General

a. One or more of the L7 spacecraft's X-Band transmitters and Gimballed X-Band Antennas (GXAs) are used to transmit the X-Band downlinks to the LGS/AGS/SGS.

b. LGS, as the primary site, receives the downlinked science data and forwards the data to Landsat Processing System (LPS) collocated at the EDC in Sioux Falls. The AGS and SGS, as secondary sites, record the data stream and send the tapes to the LGS for replay to the LPS.

c. During the period that RF line-of-sight conditions exist between the spacecraft and the LGS/AGS/SGS, wideband science data is downlinked to the LGS/AGS/SGS through the use of the Gimballed X-Band Antennas (GXAs) as scheduled by the MOC. Link operation is dependent upon RF line-of-sight conditions between the spacecraft and the LGS/AGS/SGS antenna local elevation angle being greater than 5 degrees and above the local mask. Accessibility for signal acquisition purposes is not precluded by the spacecraft for LGS/AGS/SGS antenna local elevation angles greater than 1 degree.

4.2.1.1 X-Band Services

Science data are sent from the spacecraft to the ground stations over the X-Band links. Transmission from the spacecraft to LGS/AGS/SGS of real-time science data from the ETM+ payload will be at a data rate of 150 Mbps. Recorded ETM+ payload data will be played back by the Solid State Recorders (SSRs) at a data rate of 150 or 300.0 Mbps and transmitted by the spacecraft to the LGS/AGS/SGS over one or two 150.0 Mbps links. Up to three separate 150 Mbps downlinks are supported by the spacecraft to provide a combination of real-time and recorded science data to one or more ground stations. The AGS/SGS will be capable of receiving one link while LGS will be capable of receiving three. Two are expected during nominal support.

4.2.2 Interface Performance Definition

Requirements for acceptable interface performance are detailed in paragraphs 3.2.2.1 and 3.3.2. Both the spacecraft and the LGS/AGS/SGS shall comply with these requirements, as applicable.

4.2.3 Interface Characteristics

4.2.3.1 General

The interface links between the LGS/AGS/SGS and the spacecraft are:

a. L7 to LGS/AGS/SGS X-Band Downlink Number 1 (Low Frequency)

b. L7 to LGS/AGS/SGS X-Band Downlink Number 2 (Mid Frequency)

c. L7 to LGS/AGS/SGS X-Band Downlink Number 3 (High Frequency)

4.2.3.2 Interface Design

The functional design of each of the L7 spacecraft/LGS/AGS/SGS RF links are as specified in paragraph 4.2.4. Pertinent communications signal design and system performance requirements of the LGS/AGS/SGS and spacecraft are also specified. The major link parameters and characteristics are shown in Table 4-1.

4.2.4 Link Functional Design and System Constraints

4.2.4.1 General

a. X-Band downlink service to the LGS/AGS/SGS will be available during intervals when a L7 spacecraft-to-LGS/AGS/SGS line-of-sight exists with ground station local elevation angles greater than or equal to 5 degrees, as scheduled by the MOC. The science data transmitted on this link will originate at the Enhanced Thematic Mapper Plus (ETM+) payload. The science data stream may be transmitted as it is acquired by the instrument (i.e., real-time) or recorded on the Solid State Recorder (SSR) and played back at a later time for transmission to the ground.

b. The L7 spacecraft will have the capability to transmit up to three data streams supporting ground stations. Each data stream contains ETM+ payload d ata which consists of ETM+ imagery, calibration data, and payload correction data (PCD). Transmission can be at any of the three frequencies listed in Table 4-1. Each data stream has a rate of 150 Mbps.

4.2.4.2 Link Type

Each X-Band downlink can carry one of the following data options:

a. One 150 Mbps real-time data stream from the ETM+ payload.

b. One 150 Mbps playback stream.

Table 4-1. L7-To-LGS/AGS/SGS X-Band Downlink Interface Characteristics

Parameters	Comments
Frequencies	8082.5 MHz, 8212.5 MHz, 8342.5 MHz
Modulation	AQPSK
Data Rate (Total)	149.828 Mbps +/- 0.015 Mbps
Transmit Axial Ratio	< 3.5 dB over +/- 1.2° from boresight
Sidelobes	> 17 dB below peak
EIRP (Minimum)	24.2 dBW over +/- 1.2° from boresight
Frequency Stability	+/- < 50 PPM total over life and temperature
Phase Non-Linearity	< 6° over +/- 40 MHz
Gain Flatness	< .6 dB over +/- 40 MHz
Data Rise and Fall Time (10% to 90%), Measured at Input to Solid State Power Amplifier	< 4.0 nanoseconds
QPSK Phase Imbalance	< +/- 4°
QPSK Amplitude Imbalance	< +/- 0.25 dB (I or Q Channel)
3 dB Bandwidth	110.0 MHz
Doppler	<190 KHz
BER	10^{-5} (Note 1)
Incidental AM Up To 2 KHz	< 1 %
Phase Noise 10 KHz To 75 MHz	< 2° RMS
Data Format	NRZ-L
AM/PM	< 4°/dB
Data Asymmetry	< 5 %
Polarization	RHCP
I/Q Ratio	1:1 +/- 0.8 dB
Ground Station G/T (El angle=5°)	
At LGS	31.6 dB-k
At AGS	36.0 dB-k
At SGS	35.4 dB-k

(Note 1) At Ground Station Interface

c. A second 150 Mbps playback data stream.

Each 150.0 Mbps link consists of two 75.0 Mbps data streams which are modulated on the In-phase (I) and Quadrature (Q) channels.

4.2.4.3 Functional Description

The functional interface of this link is shown in Figure 4-1. Real-time ETM+ or recorded ETM+ payload data is provided by the baseband switching unit (BSU) for routing to the appropriate X-Band transmitters. 75 Mbps I and Q channel data streams from the BSU are input to the appropriate X-Band Transmitter. Within the X-Band transmitter, data from the BSU is input to the baseband driver which reclocks the incoming NRZ-L data and drives the AQPSK modulator. I and Q channel data from the baseband driver are AQPSK modulated onto the X-Band carrier with an I/Q channel power ratio of 1:1, as shown in Figure 4-2. The transmit carrier is derived from a Phase Locked Dielectric Resonator Oscillator (PL-DRO). The output of the AQPSK modulator is input to a solid state power amplifier (SSPA) within the X-Band Transmitter which amplifies the AQPSK modulated signal to provide the necessary output power. The amplified AQPSK-modulated signal is transmitted at the appropriate carrier frequency to the LGS/AGS/SGS via a RHCP GXA.

Within the ground station, the input signal from the receive antenna is downconverted before being input to the AQPSK receiver/demodulator. A separate tracking receiver is utilized for antenna tracking purposes. The AQPSK receiver/demodulator demodulates the downconverted signal into separate I and Q channel data streams with NRZ-L format. Following AQPSK demodulation, the bit synchronizer provides I and Q channel data clock recovery. For the LGS, the outputs (data and clock) from the bit synchronizer are provided to the Landsat Processing System (LPS) at Sioux Falls for data storage and processing. For the AGS/SGS, the outputs (data and clock) from the bit synchronizer are sent to recorders for subsequent playback at the LGS. This interface is described in Section 6.2.2.2. The LPS will resolve the I and Q channel ambiguity using the CCSDS Virtual Channel Data Unit (VCDU) header.

4.3 Baseband Signal Characteristics

4.3.1 General

This paragraph provides a description of the baseband signal characteristics of the X-Band downlink signal to the LGS/AGS/SGS.

4.3.2 Science Data Baseband Signal Parameters

The science data baseband signal in the spacecraft is a NRZ-L waveform as shown in Figure 4-3.

4.3.3 Science Data Frame Format

4.3.3.1 X-Band Science Data Format

a. All L7 science data will be formatted for transmission at 150.0 Mbps over the X-Band link. With the exception of PN fill data, the delivery service will be equivalent to the Grade 3 service defined in CCSDS 701.0-B-1, *Advanced Orbiting Systems, Networks and Data Links: Architectural Specification*. Through the application of a BCH error

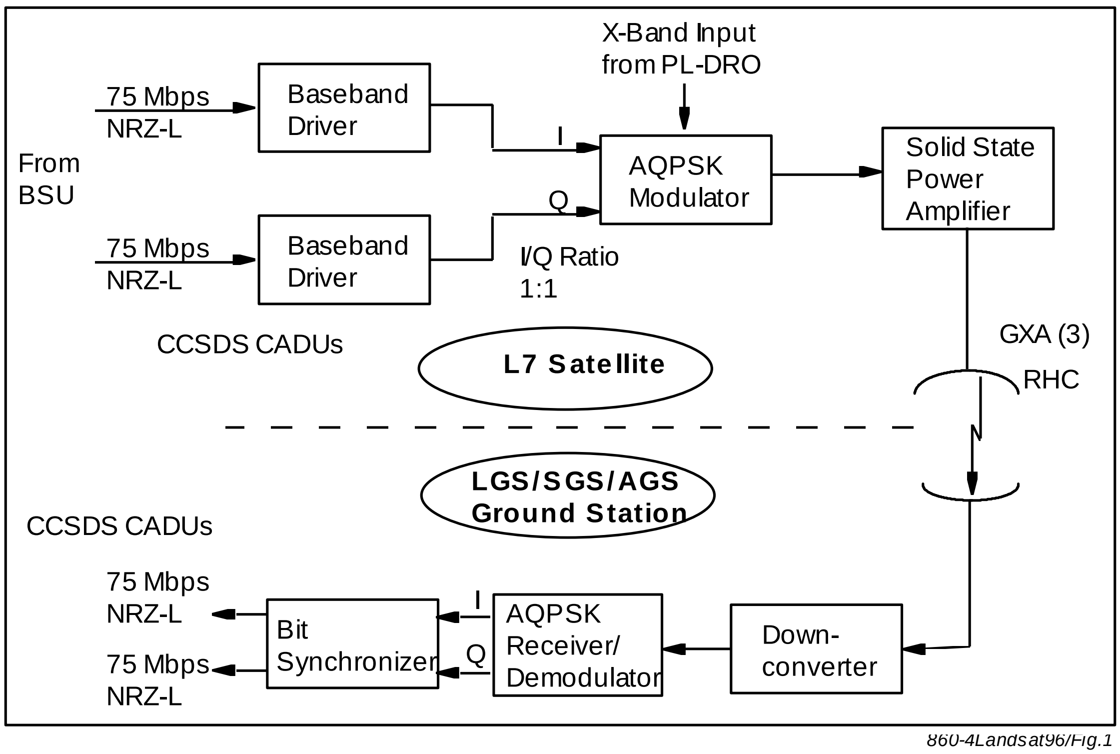
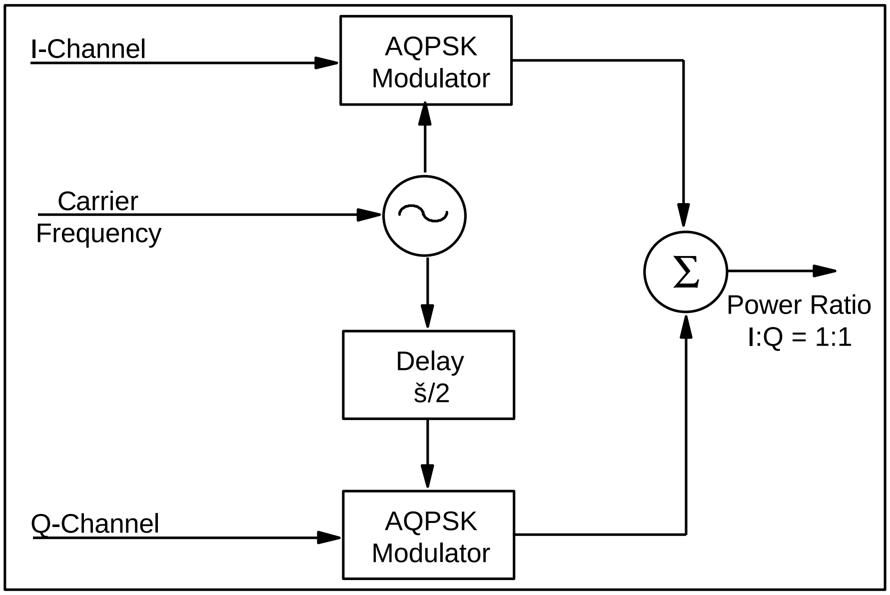
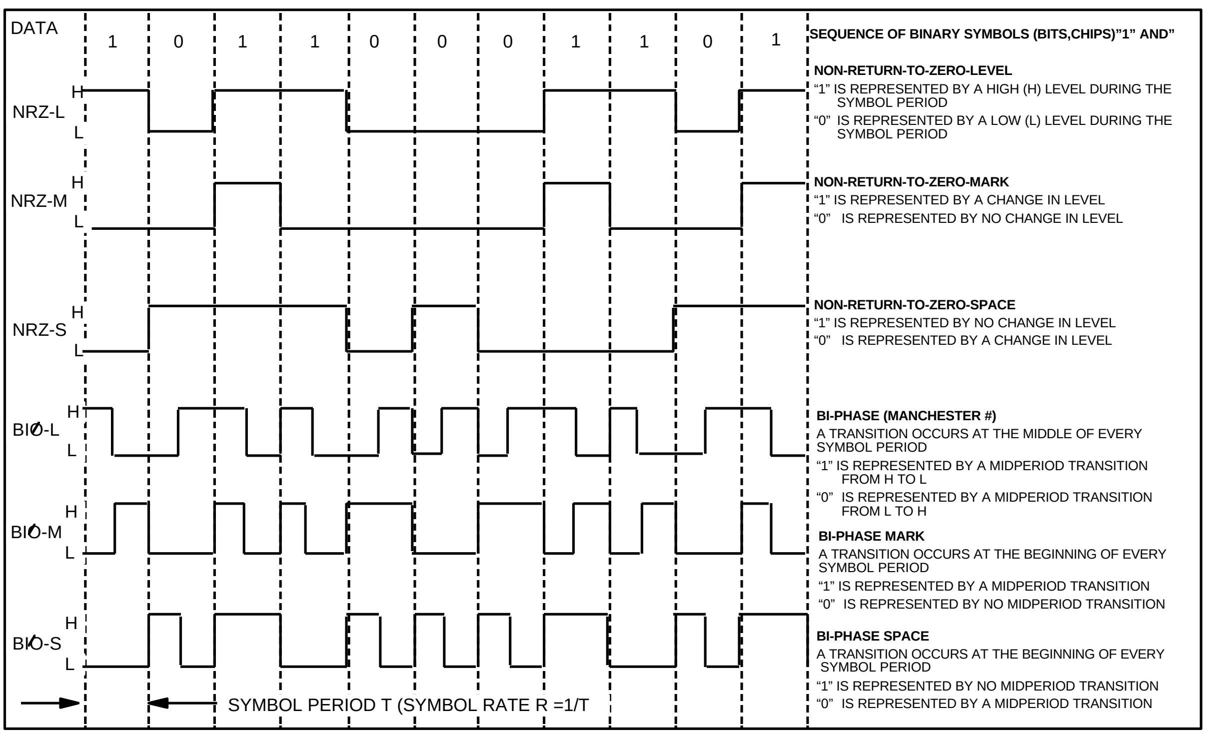


Figure 4-1. L7-to-LGS/SGS/AGS X-Band Downlink Configuration



860-4Landsat96/Fig.2

Figure 4-2. X-Band Downlink Modulation Functional Configuration



860-4Landsat96/Fig.10

Figure 4-3. Digital Data Formats

correction code to the science data, both real-time ETM+ payload science data and recorded data from the ETM+ payload will have a BER of < 10^{-6}. The LGS/AGS/SGS do not provide BCH decoding. Therefore, the ground stations will only provide a 10^{-5} BER at the ground station output. The Landsat Processing System (LPS) at Sioux Falls will provide the required 10^{-6} BER after processing the data stream. See Figure 4-4 for the downlink transfer frame format. PN fill data will not be structured in CCSDS CADUs. The spacecraft is capable of transmitting PN fill data over the X-Band link. This mode will be used to conduct, BER testing, primarily during early orbit.

b. Data is formatted by the ETM+ payload into separate mission data streams which are provided as a single bit stream for BCH encoding. Data streams consist of 992-bit data blocks of payload data. Data blocks are segmented into a BCH data unit which contains a predefined data zone of 7936 bits, a BCH EDAC field, a data pointer, and a BCH EDAC field for the data pointer. Each BCH data unit is encapsulated in a Virtual Channel Data Unit (VCDU) which contains a VCDU header, data zone, and VCDU error control field. Data are transmitted serially in CCSDS CADUs which encapsulate the VCDUs.

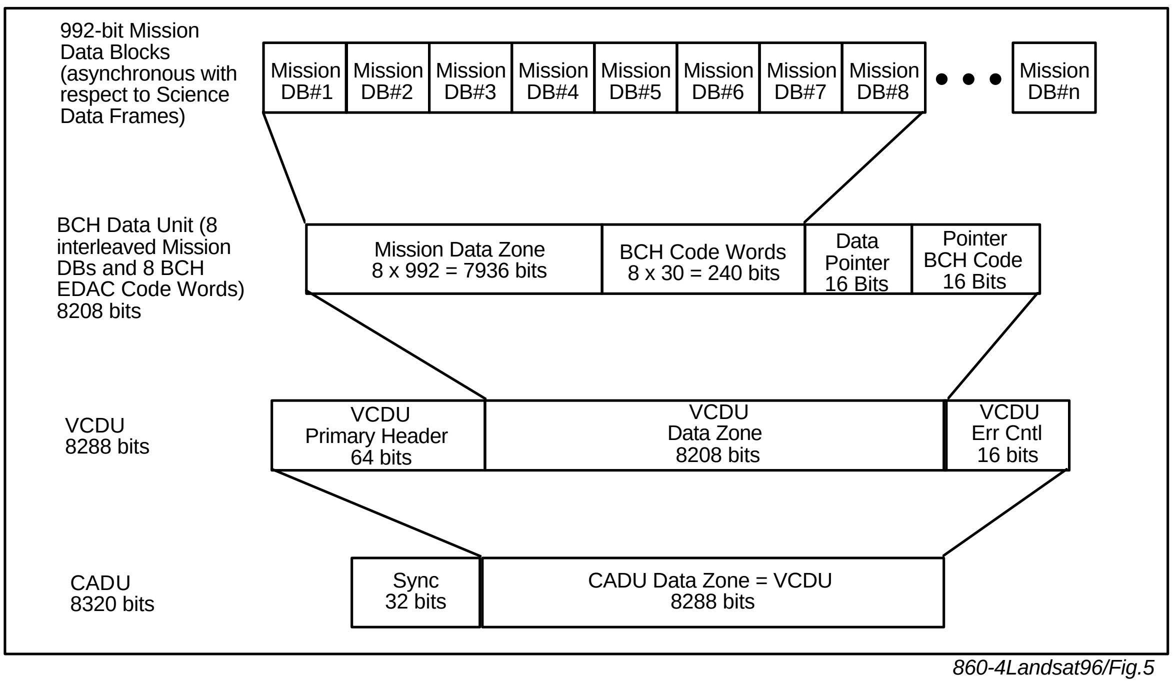


Figure 4-4. X-Band Channel Access Data Unit (Sync + Virtual Channel Data Unit)

4.3.3.2 BCH Coding on X-Band Downlink Data

The X-Band direct downlink data will have a (1023,993,3) BCH code with interleave depth I = 8. The BCH encoder output is 1023 bits (for each input data block of 993 bits). The input consists of 992 bits of science data and one fill bit. Only the 992 bits of science data are transmitted to the ground. The fill bit ("0") is added, on the ground, prior to decoding. The error correction code word corresponding to each input data block has a length of 30 bits. The code will correct up to three bit errors per block. Figure 4-3 shows the organization of BCH data blocks and code words within each BCH data unit. The (1023,993,3) BCH encoder is shown in Figure 4-5.

4.4 RF Signal Characteristics

4.4.1 X-Band Downlink Signal Characteristics

4.4.1.1 General

For the L7-to-LGS/AGS/SGS X-Band downlink, balanced AQPSK modulation (channel power ratio of 1:1) is used as shown in Figure 4-2. This link will not provide a ranging capability. The carrier frequency for the X-Band downlink is derived from the Phased Locked Dielectric Resonator Oscillator (PL-DRO).

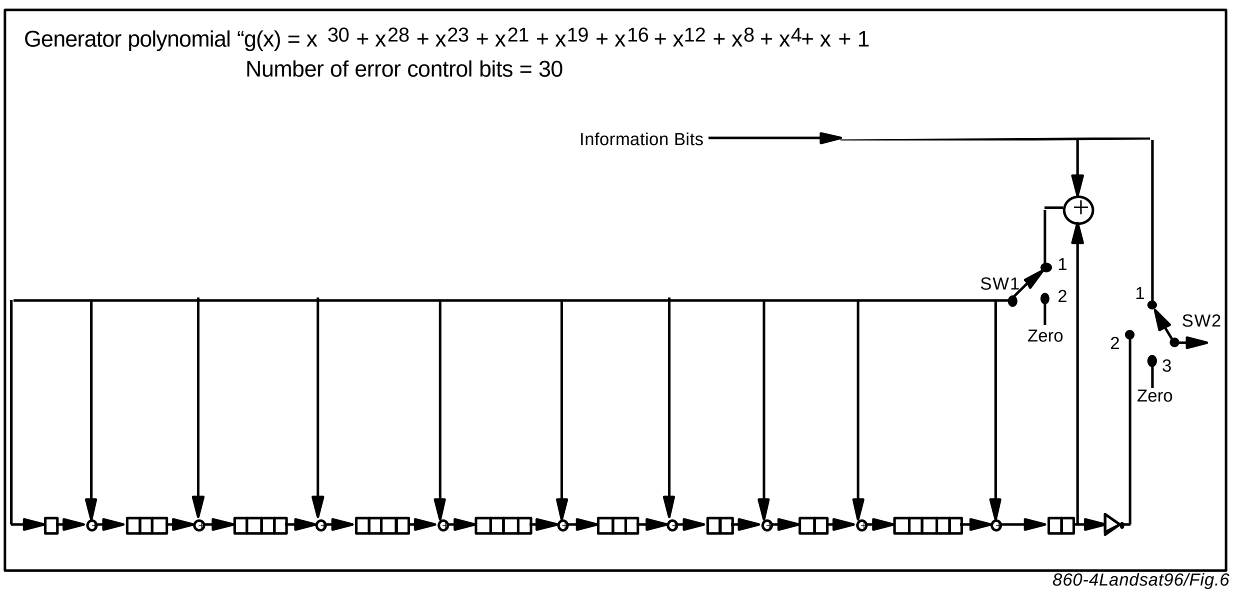


Figure 4-5. (1023, 993, 3) BCH Code Generator - X-Band Science Data

4.4.1.2 RF Requirements

The spacecraft is required to close the link for an LGS G/T greater than or equal to 31.6 dB/K, an AGS G/T greater than or equal to 36.0 dB/K, an SGS G/T greater than or equal to 35.4 dB/K, during a rain rate of 4 mm/hr at a 5 degree local elevation angle. The spacecraft is required to provide the capability to transmit each 150 Mbps X-Band downlink with a minimum 24.2 dBW EIRP in the direction of the LGS/AGS/SGS.

4.4.1.3 Signal Characteristics

The characteristics of the X-Band downlinks are in accordance with Table 4-1. AQPSK modulation is employed. The X-Band carrier is modulated by the I and Q baseband signals. The X-Band downlinks use the Gimballed X-Band antennas (GXAs) on the spacecraft.

4.4.1.4 Frequency Stability

4.4.1.5 Transmitter Center Frequency Stability

The X-Band transmitter uses a single fixed-frequency reference for the transmitter. The frequency reference source is a Phased Locked Dielectric Resonator Oscillator (PL-DRO). The frequency characteristics are referenced in Table 4-1.

4.5 Downlink Acquisition and Tracking

4.5.1 General

The spacecraft will be tracked via the LGS/AGS/SGS ground stations' X-Band autotrack capability.

4.5.2 Carrier Acquisition and Tracking Threshold

The carrier loop in the ground station X-Band tracking receiver will automatically acquire and track the modulated or unmodulated carrier signals received within ±800 KHz of the nominal carrier frequency, provided that the received Signal-to-Noise Ratio (SNR) in the loop noise bandwidth of 50 KHz is at least 10 dB and that the received SNR in the second Intermediate Frequency (IF) bandwidth of 12 MHz is at least 3 dB. Operationally, if X- and S-Band signals are present, the strongest of the signals will be used for auto tracking.

4.6 Predicted Performance Degradation Due to Signal Distortion and Receiver/Demodulator Impairments

The E_b/N_o performance degradation to the X-Band downlink, due to the best predicted signal distortion parameters values listed in Table 4-1 and the best predicted ground receiver system loss, has been analyzed by the Communications Link Analysis Simulation System (CLASS) and determined to be 5.5 dB. The 5.5 dB includes 2.5 dB for triplexer filter distortion loss and the 3.0 dB allocation for the signal distortions and ground receiver system losses (Refer to PIR U-S/C-L7-0050). The 5.5 dB loss is included in the item "ground implementation loss" of the link budget in Appendix A.

Section 5. S-Band Link Interface Characteristics

5.1 Purpose

This section describes the functional design of each LGS/AGS/SGS/WPS S-Band link identified in Section 3 using illustrative end-to-end functional configuration descriptions. Pertinent L7 spacecraft and LGS/AGS/SGS/WPS communications system performance requirements are also provided.

5.2 Functional Interface Utilization

The LGN consists of GSFC-managed stations at Fairbanks, Alaska, Spitzbergen, Norway, and Wallops Island, Virginia and the MMO/DHF-managed LGS. The LGS station at Sioux Falls has a 10-meter antenna. The AGS, SGS, and WPS have 11.3-meter antennas. The spacecraft is accommodated by LGS/AGS/SGS/WPS communications support through the use of the L7 S-Band transponder STDN link mode. Support is dependent upon RF line-of-sight conditions and when LGS/AGS/SGS/WPS antenna elevation angle is above the local mask and greater than 5 degrees above the horizon. The following S-Band services are available from the LGS and WGS to the L7 mission:

a. Telemetry. Transmission from the spacecraft to LGS/AGS/SGS/WPS of digital real-time telemetry and memory dump data will be at a data rate of 4.864 Kbps (high rate mode). Digital real-time telemetry may also be transmitted at a data rate of 1.216 Kbps (low rate mode). Telemetry data stored in the Solid State Recorder (SSR) will be transmitted from the spacecraft to LGS/AGS/SGS/WPS at a data rate of 256.0 Kbps.

b. Commands. Transmission from the LGS/AGS/SGS/WPS to the spacecraft of command data formatted in accordance with the requirements outlined in paragraph 3.3. The uplink data rate is 2.0 Kbps.

c. Doppler Tracking. The LGS/AGS/SGS/WPS shall generate two-way Doppler tracking that is derived from the spacecraft-to-LGS/AGS/SGS/WPS S-Band carrier, which is a coherent turnaround of the LGS/AGS/SGS/WPS-to-spacecraft carrier. The LGS/AGS/SGS/WPS shall generate one-way Doppler tracking that is derived from the L7-to-LGS/AGS/SGS/WPS S-Band carrier, to support characterization of oscillator drift in L7 transmitter.

All three WGS sites and the LGS provide command and telemetry services. Section 6 contains additional information about expected service usage at each site.

5.3 Interface Performance Definition

Requirements for acceptable performance are detailed in paragraphs 3.2.3 and 3.3.3 through 3.3.5. LGS/AGS/SGS/WPS support must comply with these standards.

5.4 Interface Characteristics

5.4.1 General

The interface links between the LGS/AGS/SGS/WPS ground stations and the spacecraft are:

a. LGS/AGS/SGS/WPS to L7, S-Band Uplink.

b. L7 to LGS/AGS/SGS/WPS, S-Band Downlink.

5.4.1.1 Interface Design

The functional design of each of the LGS/AGS/SGS/WPS/L7 S-Band RF links are as specified in this section. Pertinent communications signal design and system performance requirements of the LGS/AGS/SGS/WPS and spacecraft are also specified. The major link parameters and characteristics are shown in Tables 5-1 and 5-2.

Table 5-1. LGS/AGS/SGS/WPS-to-L7 S-Band Uplink Interface Characteristics

Parameter	Value
Command Data Rate	2000 Bps
Subcarrier Frequency	16 KHz +/-0.001% (Note 1)
Modulation Signal Type	NRZ-M
Carrier Modulation	Phase Modulation, 0.7 radian +/-10%
Uplink Center Frequency	2106.40625 MHz +/- LGS/AGS/SGS/WPS to L7 Doppler Shift
LGS/AGS/SGS/WPS Antenna Diameter	10 / 11.3 Meters
Spacecraft Antenna Polarization	LHCP (Omni)
LGS/AGS/SGS/WPS Minimum EIRP	94.8 / 97.0 dBm
Spacecraft Minimum G/T 80% Spherical Coverage +/-64° Earth Viewing Cone	 -40 dB/K -50 dB/K

Note:

1. The 2000 Bps Command Data Bit Clock will be coherent with the 16 KHz Subcarrier.
2. The Uplink BER Requirement is 10^{-6}.

Table 5-2. L7-to-LGS/AGS/SGS/WPS S-Band Downlink Interface Characteristics

Information			**Baseband Information**			**Subcarrier Information**			**Carrier**			**Required Equipment Carrier Power at Data Threshold[1,2] (dBW)**	
Link Number	**Data**	**Data Rate (Kbps)**	**Format**	**Modu-lation**	**Fre-quency**	**Format**	**Modu-lation**	**Fre-quency**	**Frequency[3]**	**Ant. (Polari-zation)**	**Min. EIRP (dBW)**	**LGS**	**WGS**
Subcarrier:													
10A	Real-Time	4.864	N/A	N/A	N/A	BI Φ -s	PSK	1.024 Mhz	Mode 1 or Mode 2	Omni (LHC)	1.7 (Note 4)	-124.3	-122.8
10B	Real-Time	1.216					b= 0.8 RAD	±0.0001 %			-7.5 (Note 5)	-130.4	-128.9
10C	Real-Time	4.864										-124.4	122.9
10D	Real-Time	1.216										-130.5	-129.0
Baseband:													
10C	SSR Play-back	256.0	BI Φ -s	PM b= 1.0 RAD (Peak Rect-angular) ±10%	N/A	N/A	N/A	N/A	Mode 1 or Mode 2	Omni (LHC)	1.7 (Note 4)	-116.3	114.8
10D	SSR Play-back	256.0									-7.5 (Note 5)	-116.3	114.8

Notes:

1. Equivalent carrier power measured at the AGC for a BER of 10^{-5}.
2. Values calculated by computing the difference between the received carrier power and the available channel (baseband or subcarrier) margin, at maximum range.
3. Mode 1: Coherent, (240/221) X U/L Freq.
   Mode 2: Non-coherent, 2287.5 Mhz +/- 0.0015%.
4. The stated EIRP corresponds to 80% antenna spherical coverage.
5. The stated EIRP corresponds to 64 degrees earth cone coverage.

5.4.2 Link Functional Design and System Constraints

5.4.2.1 General

The spacecraft S-Band transponder is used in the STDN mode for this link.

5.4.2.2 Uplink Characteristics

The S-Band link is used to provide command data to the spacecraft from the LGS/AGS/SGS/WPS.

5.4.2.2.1 Functional Description

The functional interfaces are shown in Figure 5-1. The major link parameters and characteristics are shown in Table 5-1.

For this link, commands originating at the L7 Mission Operations Center (MOC) are encoded into the NRZ-M format and transmitted to the ground station where they can be buffered and sent to L7 at 2.0 Kbps. The modulator of the Programmable Telemetry Processor (PTP) in LGS and the General Data Products Model 782 PSK subcarrier generator of AGS/SGS/WPS ground stations generate a subcarrier frequency of 16 KHz that is divided by 8 to provide the 2 KHz frequency employed for data buffering in the PTP and in subcarrier generators. The formatted command is used to phase shift key (PSK) modulate the 16 KHz subcarrier. The modulated subcarrier will phase modulate (PM) the uplink transmitter at the LGS/AGS/SGS/WPS ground stations. The transmitter operates at a frequency of 2106.40625 MHz.

The spacecraft's S-Band transponder provides transmission and reception of standard LGS/AGS/SGS/WPS signals via the STDN mode. The transponder acquisition and tracking characteristics are discussed in paragraph 5.4.4. The uplinked signal is received at the spacecraft, via the omni antennas by the S-Band transponder where the PM signal is utilized to generate the coherent downlink transmitter frequency and demodulated to provide the baseband signal. The 16 KHz baseband subcarrier signal is then demodulated and passed to the C&DH subsystem from which command data in the NRZ-M bit stream are detected, decoded and processed.

Each omni antenna is left-hand circularly polarized (LHCP). The omni antennas are configured to give at least 80 percent S-Band spherical coverage on receive and commandable hemispherical/spherical coverage on transmit. The spacecraft communicates with the LGS/AGS/SGS/WPS through the nadir omni. The spacecraft can also communicate with the LGS/AGS/SGS/WPS through the zenith omni antenna should attitude control be lost.

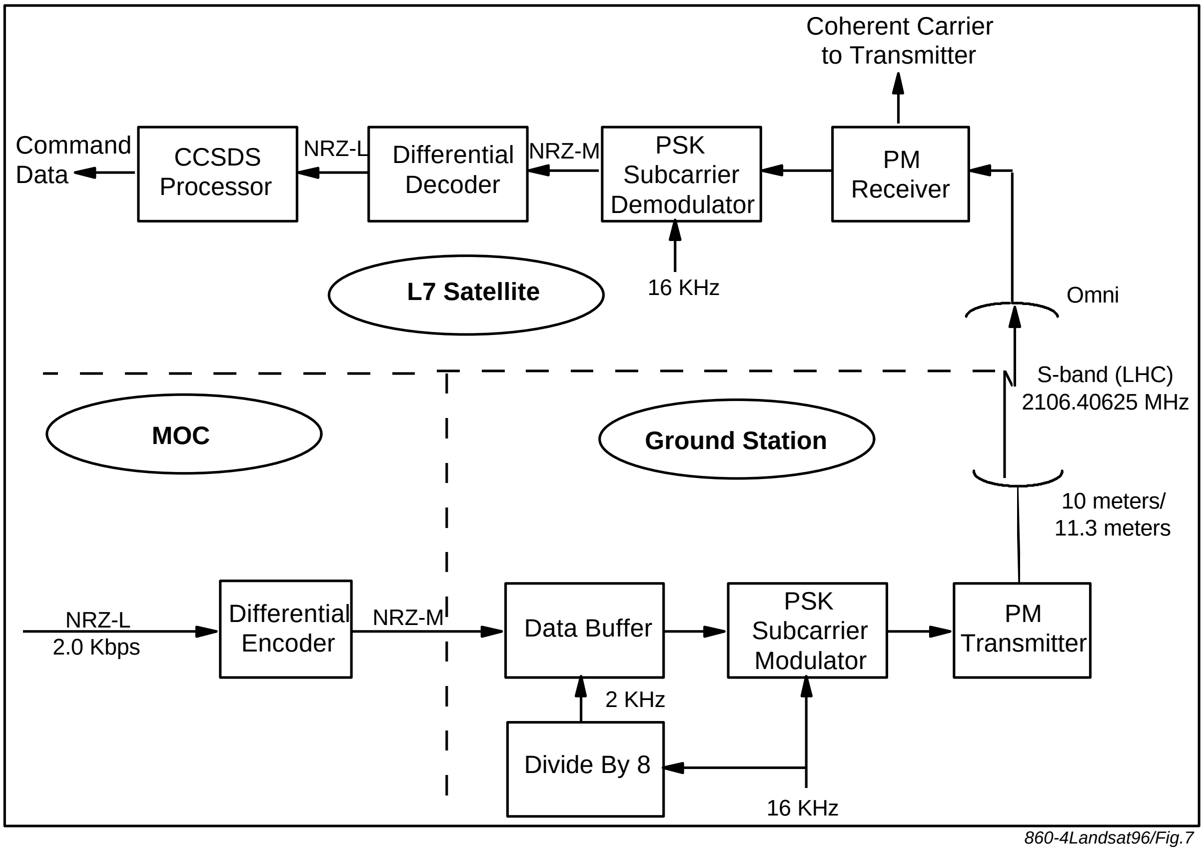


Figure 5-1. L7-to LGS/SGS/AGS/WPS-S-Band Uplink Configuration

5.4.2.2.2 Signal Characteristics

The bit modulation of the transmitted carrier is 2.0 Kbps NRZ-M which has modulated a 16 KHz sinusoidal subcarrier. Additional characteristics of the PSK/PM command mode are:

Clock Frequency: 2.0 KHz; accuracy: ±100 ppm

Subcarrier Frequency: 16.0 KHz; accuracy: ±0.16 Hz

The characteristics of LGS/AGS/SGS/WPS command functions are in accordance with Table 5-1.

5.4.2.3 Downlink Characteristics

The L7 spacecraft's S-Band transponder is used as the data transmitter for this link. Baseband characteristics are in accordance with Table 5-2. The S-Band downlink subcarrier is used to transmit real-time housekeeping telemetry data from the spacecraft to the LGS/AGS/SGS/WPS. In addition, baseband SSR playback data may be transmitted simultaneously with the subcarrier real-time telemetry, when commanded.

5.4.2.3.1 Functional Description

The functional interface of this link is shown in Figure 5-2. Data are received by the L7 S-Band transponder from the C&DH Subsystem in NRZ-M format and converted to the Biphase-S (Biø-S) format. The telemetry data at 4.864 or 1.216 Kbps are PSK modulated onto a 1.024 MHz subcarrier. SSR playback data at a data rate of 256.0 Kbps are phase modulated on the baseband channel, when SSR playback is commanded. The PSK subcarrier is summed with the baseband channel data, and this composite signal is used to phase modulate the transmitter in the transponder. The frequency of the transmitter is controlled either by a coherent carrier signal from the uplink receiver (see Figures 5-1 and 5-2) or by a local oscillator in the spacecraft's Communications Subsystem. The nominal output frequency of the transmitter is 2287.5 MHz (2106.40625 x 240/221) with the exact frequency being determined by the reference source in use.

The LGS/AGS/SGS/WPS ground stations employ a PM receiver which demodulates the transmitted signal. The output of the PM receiver supplies signals to the PSK demodulator for recovery of the real-time telemetry data. The demodulator output is processed by a bit synchronizer to provide telemetry data at the correct bit rate in the NRZ-L format. When two data streams are transmitted, another bit synchronizer is utilized to obtain the SSR playback data.

5.4.2.3.2 Signal Characteristics

The characteristics of the S-Band LGS/AGS/SGS/WPS downlink are in accordance with Table 5-2. Linear phase modulation is employed. The carrier is modulated by a linearly summed baseband signal and a 1.024 MHz subcarrier. The subcarrier is PSK modulated with 4.864 or 1.216 Kbps telemetry data using the Biø-S encoded format. The S-Band LGS/AGS/SGS/WPS downlink uses the spacecraft's LHCP S-Band omni antennas.

5.4.3 Baseband Signal Characteristics

5.4.3.1 General

This paragraph provides a description of the command and telemetry baseband characteristics of the spacecraft.

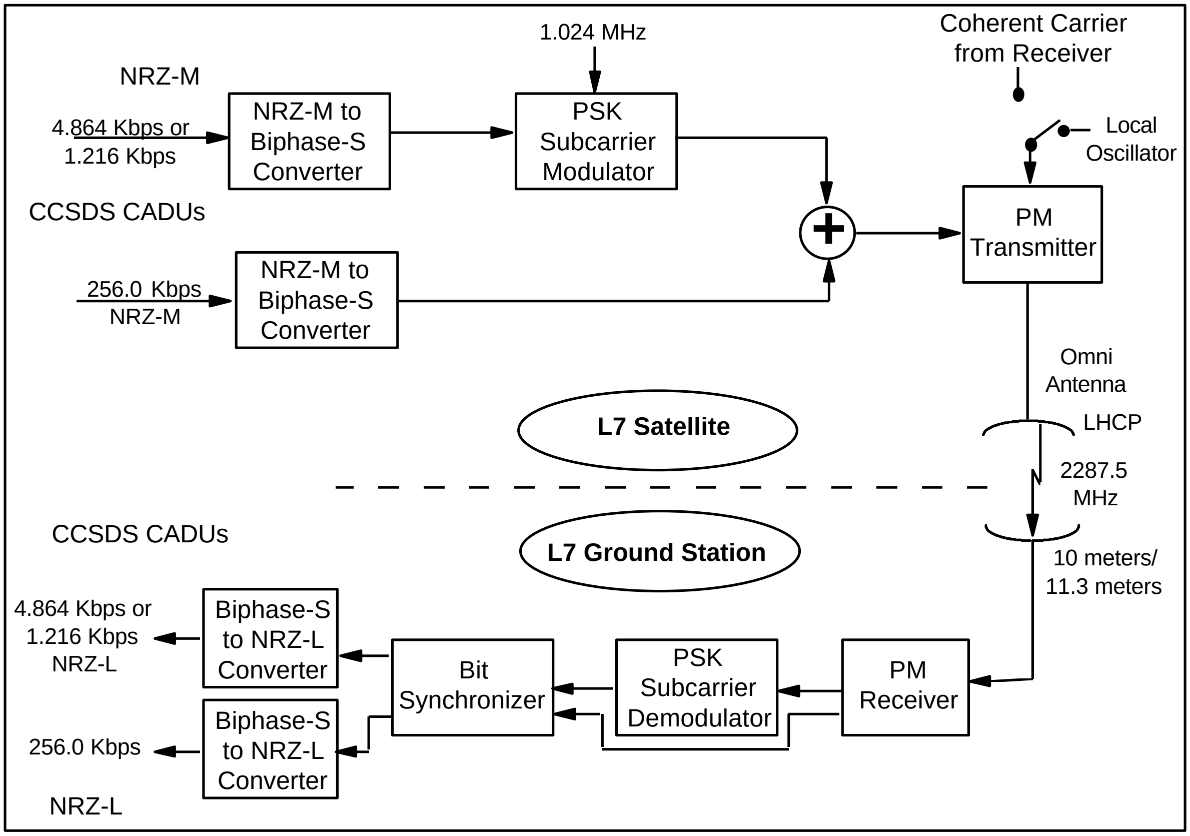


Figure 5-2. L7-to LGS/SGA/AGS/WPS-S-Band Downlink Configuration

5.4.3.2 S-Band Command Data Frame Format

The S-Band forward link command data is a serial 2.0 Kbps NRZ-M data stream. The format for S-Band commands is compatible with the CCSDS recommendations for telecommand service. The format for the uplink is shown in Figure 5-3. Commands are sent as data within a segment, and the segments are enclosed in CCSDS transfer frames. The transfer frames are Bose-Chaudhuri-Hocquenghem (BCH) encoded into short, fixed length (64 bits) Telecommand Codeblocks as shown in Figure 5-3. Each CCSDS transfer frame is transmitted as a sequential set of Telecommand Codeblocks encapsulated by a Command Link Transmission Unit (CLTU). The CLTU begins with a 16 bit start (sync) sequence and ends with a 64-bit tail sequence. The maximum length of each code block segment is 249 bytes (1992 bits), as shown in Figure 5-3. Thus, the maximum number of commands per CLTU is 62. Each CLTU is preceded by an acquisition sequence and followed by an idle sequence. The acquisition sequence is 16 bytes of alternating 'ones' and 'zeroes' beginning with either a "one" or "zero." The idle sequence is 8 bits of alternating 'ones' and 'zeroes' starting with a "zero."

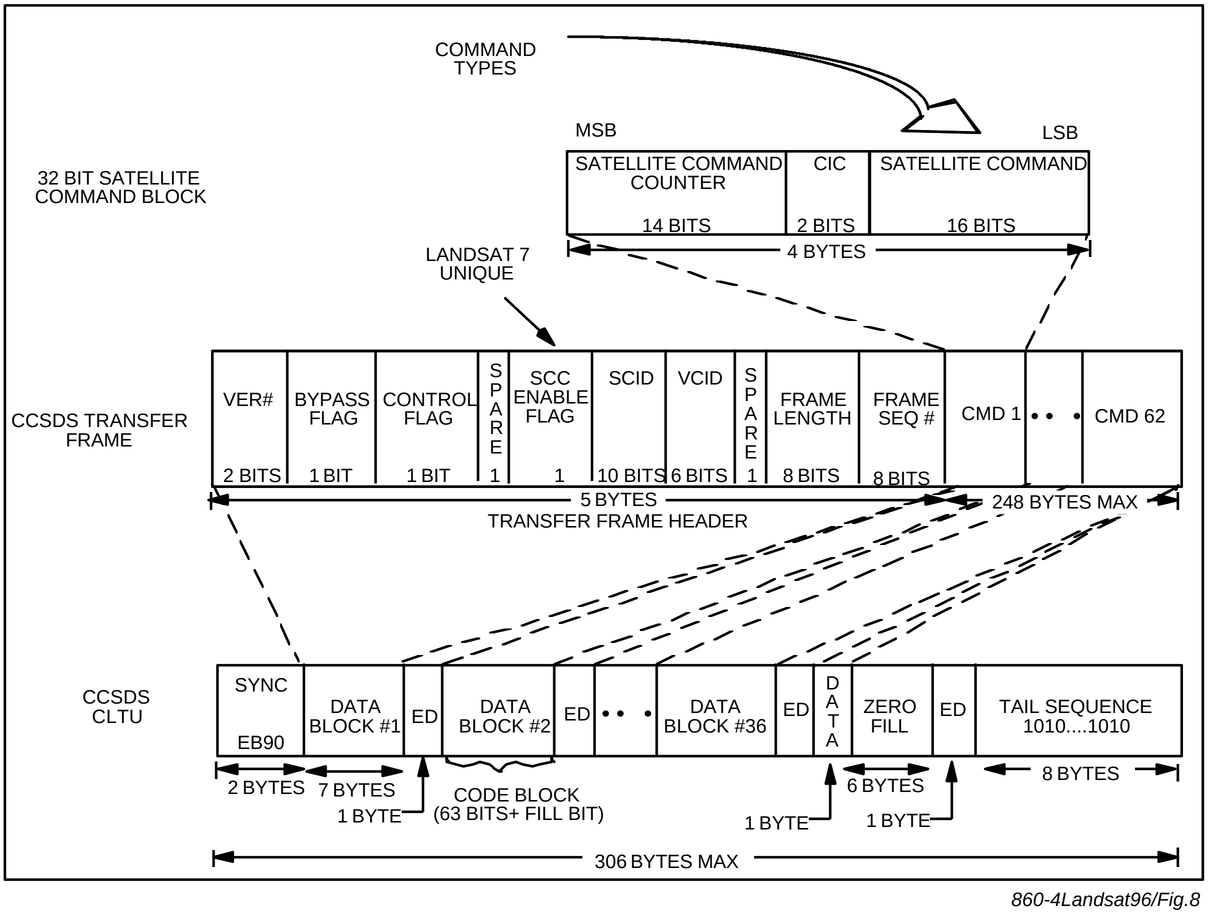


Figure 5-3. S-Band Command Format

5.4.3.3 S-Band Command Encoding/Decoding

Telecommand Codeblocks transmitted over the S-Band forward link are encoded by the MOC using a (63,56) modified BCH code, as specified in CCSDS 201.0-B-2, *Telecommand Recommendation, Part 1, Channel Service*. The Codeblock size is 64 bits, as shown in Figure 5-3. The BCH encoder is shown in Figure 5-4. The BCH decoder on the spacecraft will be operated in the three-error detection mode, since the use of NRZ-M eliminates the value of the single-error correction capability of the BCH code.

5.4.3.4 Command Baseband Signal Characteristics

The command baseband signal is an NRZ-M waveform for LGS/AGS/SGS/WPS. The command encoder in the MOC changes the NRZ-L waveform to NRZ-M. The uplink carrier is phase modulated by a 16 KHz PSK command subcarrier. Uplink carrier modulation indices (peak phase in radians) are shown in Table 5-3.

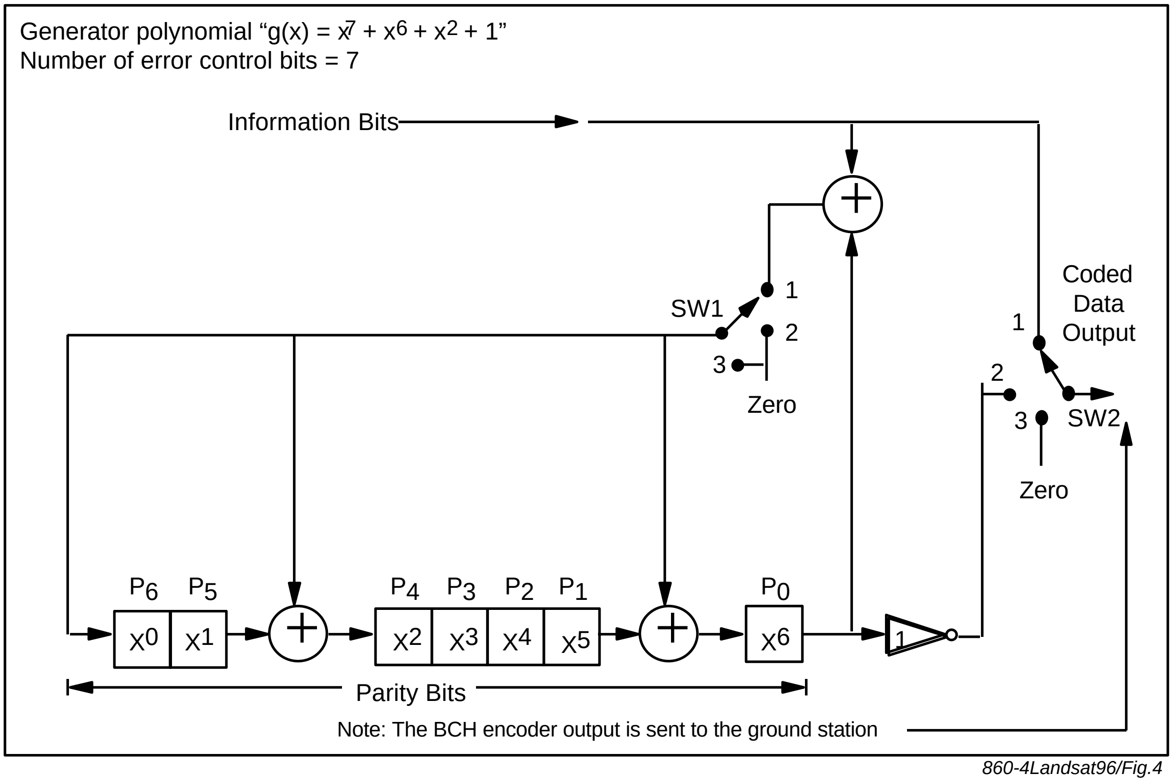


Figure 5-4. Modified BCH Code Generator - S-Band Command Link

Table 5-3. Uplink Carrier Modulation Index

Modulation Component	Peak Carrier Phase Modulation (Radians)
16 KHz command subcarrier	0.7 ± 10%

The command data rate is 2.0 Kbps and modulation type is PCM.

5.4.3.5 Telemetry Baseband Signal Characteristics

The telemetry baseband signal for SSR playback data (256.0 Kbps) is an NRZ-M waveform at the input of the spacecraft's S-Band transponder. The transponder converts the NRZ-M waveform to the Biø-S waveform. The downlink carrier is phase modulated by the sum of a 1.024 MHz PSK modulated subcarrier containing real-time telemetry and the baseband channel SSR playback data. Downlink carrier modulation indices are shown in Table 5-4.

Table 5-4. Downlink Carrier Modulation Indices

Modulation Component	Peak Carrier Phase Modulation (Radians)
1.024 MHz Real-Time TLM Subcarrier 1.216 Or 4.864 Kbps	0.8 ± 10% (Sinusoid) - Baseband Modulation Present
Baseband Modulation: 256.0 Kbps Biø-S	1.0 ± 10% (Rectangular)

5.4.3.6 Telemetry Formats

All L7 spacecraft telemetry data transmitted over the S-Band downlinks will be sent as a class of data delivery equivalent to Grade 2 service, defined in *Advanced Orbiting Systems, Networks and Data Links: Architectural Specification*, CCSDS 701.0-B-1. See Figure 5-5 for the data format used over this link. Grade 2 service will have a BER of < 10^{-7}. The Programmable Telemetry Processors (PTPs) at each ground station will provide Reed-Solomon decoding to meet this BER. The S-Band downlink data received by the LGS/AGS/SGS/WPS will be sent to the MOC via Nascom facilities.

5.4.3.7 Reed-Solomon Outer Coding

The Grade 2 service of the S-Band downlink data will have a (255,223,16) Reed-Solomon (R-S) outer code with interleave depth I = 3. The total block length is 255 symbols (8 bits/symbol). Each block has a data field of 223 symbols and a R-S check symbol field of 32 symbols. The code will correct up to 16 symbol errors per block. Figure 5-5 depicts the construction of the CCSDS CVCDU which contains the R-S encoded data and check symbols. The (255,223,16) R-S code is characterized as follows:

a. The field generator polynomial for the (255,223,16) R-S code is:

$$F(x)= x^8 + x^7 + x^2 + x + 1 \text{ over GF (2)}$$

b. The code generator polynomial for the (255,223,16) R-S code is:

$$g(x)= \prod_{i=112}^{143}(x-\alpha^{11}i) = \sum_{i=0}^{32} G_i x^i \quad \text{over GF}(2^8), \quad \text{where } F(a)=0$$

5.4.3.8 Data Signal Formats

The telemetry data signal output from the spacecrafts C&DH Subsystem in the NRZ-M signal format is converted to biphase-S signal format. The format for biphase-S data shall conform to that shown in Figure 4-3. The telemetry data stream is converted from biphase-S to NRZ-L at the LGS/AGS/SGS/WPS prior to processing in the PTP.

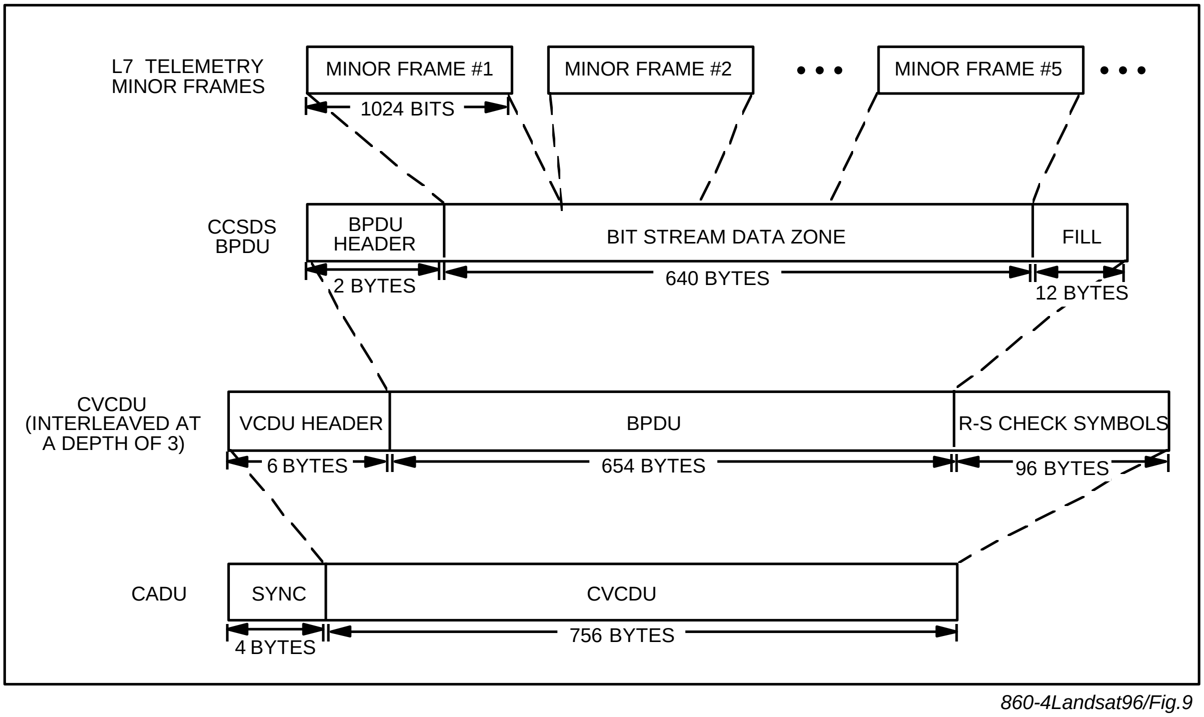


Figure 5-5. S-Band Telemetry Channel Access Data Unit (Sync + Coded Virtual Channel Data Unit)

5.4.3.9 Ranging Baseband Signal

Not applicable.

5.4.4 Transponder Acquisition and Tracking Characteristics

This paragraph provides a description of the L7 S-Band transponder acquisition and tracking characteristics in STDN mode.

5.4.4.1 Uplink

5.4.4.1.1 Acquisition Performance

The spacecraft's S-Band transponder will detect and phase lock to the uplink signal swept at rates between 5 and 35 KHz/sec. The probability of acquisition will be greater than 0.99 in a period corresponding to one sweep period when the carrier to noise density ratio is between 75 and 120 dB-Hz. The maximum sweep range is +/- 160.0 KHz. The receiver will acquire bit synchronization on receipt of an acquisition preamble consisting of 128 bits (or more) of alternating “1" and “0" data at 2 Kbps.

5.4.4.1.2 Tracking Performance

Once locked onto the uplink, the spacecraft will provide the tracking performance indicated below. This assumes carrier modulation by a 16-KHz subcarrier with a modulation index of up to 0.7 radians peak.

Tracking Range and Rate: With a signal level at the transponder input of at least -111.7 dBm (C/N_0 = 60 dB-Hz), the spacecraft will be capable of tracking +/-160 KHz about the assigned center frequency with a rate up to 35 KHz/sec.

Tracking Threshold and Reacquisition: The L7 S-Band transponder will hold lock, in the absence of frequency dynamics, for 1 minute or longer with a probability greater than 90 percent when the unmodulated signal level at the transponder input is -131.7 dBm (C/N_0 = 40 dB-Hz) or greater. The transponder receiver will reacquire without the aid of ground sweep for signal dropout durations of less than 30 msec. This is applied when tracking an uplink signal with a Doppler rate of less than 3 KHz/sec.

5.4.4.2 Downlink

The carrier loop in the LGS/WGS receivers will automatically acquire and track phase modulated or unmodulated carrier signals received within +/-250 KHz of the nominal carrier frequency, provided that the received Carrier-to-Noise Ratio (CNR) in the IF bandwidth of 12 MHz is at least -15 dB.

5.4.5 Frequency Stability

5.4.5.1 Spacecraft Center Frequency Stability

The L7 S-Band transponder uses a single fixed frequency reference for both the receiver and the transmitter. The frequency reference source is an internal temperature-compensated crystal oscillator (TCXO). The frequency characteristics are given below:

1. Setability. The receiver center frequency is initially set to within ± 0.5 ppm of the assigned channel center frequency at a temperature of 24 ± 2_C. The transmitter output frequency in the non-coherent mode is also initially set to within ± 0.5 ppm of the assigned channel center frequency at the same temperature.

2. Temperature Stability. At any temperature in the range from -10_C to +50_C, the deviation from the center frequency will not exceed 1 ppm. In the more restricted range of +10_C to +40_C, the frequency deviation will not exceed 0.3 ppm.

3. Short-term Stability. At any temperature in the range from -20_C to +60_C, the RMS fractional frequency deviation over a 3-minute period, measured with a 1-second integration time, will not exceed 0.001 ppm.

4. Long-term Stability. At any temperature in the range from 10_ C to 40_C, the frequency will not vary more than the following limits with a 10-minute integration time:

   (a) ± 0.3 ppm over any 48-hour period.

   (b) ± 0.1 ppm over any 5-hour period.

5. Aging Stability. At any temperature in the range from 10_C to 40_C, the frequency will not vary more than ± 3 ppm from the set value in any 1 year.

Section 6. Inter-Facility Data Flows

6.1 Purpose

This portion of the ICD contains the mission-specific aspects of the data flows among the WGS (which consists of the AGS, SGS, and WPS), the DHF (including the LGS), and the L7 MOC at GSFC. The sections that follow contain content and flow control requirements necessary for effective mission support for five types of communications interfaces among the DHF, WGS, and GSFC: telemetry, commands, tracking data, schedules and supporting data, and reports. For data formats covered in other documents, only the mission-unique aspects will be described in this section of the ICD. For file/data types unique to L7, complete content and format descriptions of the inter-facility data flows are provided

6.1.1 General

Figure 6-1 shows the interfaces among the L7 MOC DHF, and WGS for the delivery of required Landsat 7 products. NASA Integrated Service Network (NISN) requirements to provide the data lines and associated equipment to support these interfaces are in the Landsat 7 DMR, Section 5000. Transmission Control Protocol/Internet Protocol (TCP/IP) serves as the basis for data exchanges among Landsat 7 ground system elements. Real-time data are typically transferred via TCP/IP sockets while files are transmitted with the File Transfer Protocol (FTP). All command and S-Band telemetry transfers among the MOC, LGS, and WGS use the Internet Protocol Data Unit (IPDU) structure. The IPDU is basically a header concatenated with a CCSDS-compliant data unit (i.e. command transfer frame or telemetry CADU). The tables in Appendix C show the complete IPDU header structure and associated field definitions. Specific values applicable to Landsat 7 telemetry and commands are found in Sections 6.2 and 6.3 respectively. Tracking data, schedule files, and reports are all file-based transfers with the originator “pushing” the files to the recipient. Details about these types of data are in Sections 6.4 through 6.6.

Information necessary for IP transfers includes network addresses, port numbers, and passwords. Since these can change during the mission, they will not be documented in this ICD. Operations agreements, memoranda of understanding, and similar arrangements or documentation will provide these parameters.

6.2 Telemetry Interface

6.2.1 General

Landsat 7 downlinks science and spacecraft telemetry in the X and S frequency bands, respectively. The formats and rates for these data streams as telemetered from the spacecraft to the ground are covered in Sections 4 and 5 of this ICD. For Landsat 7, both the S- and X-Bands are received at LGS, SGS, and AGS while WPS receives S-Band only.

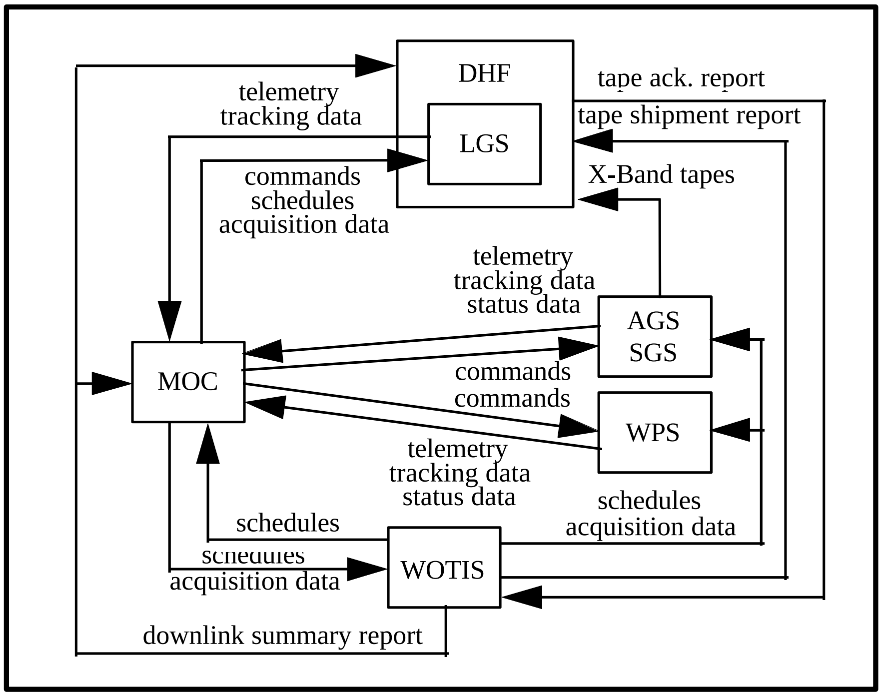


Figure 6-1. MO&DSD-WGS-LGS Interface Diagram

According to operations procedures, approximately twelve minutes before a scheduled contact at a WGS site, line verification is accomplished by the ground station front-end processor transmitting test IPDUs to the MOC. The test data stream contains IPDUs with the test flag set to “1”. The data portion contains CADUs with valid Landsat 7 synchronization patterns but the actual telemetry is a repeating pattern of ones and zeroes. During this pre-pass checkout period, which lasts until four minutes before AOS, the FOT/MOC typically exchanges test commands and command echoes with the ground station. The command/command echo process is described in paragraph 6.3.1. The checkout period ends two minutes before AOS, when the transmission of test telemetry stops. A similar checkout may be conducted between the LGS and the MOC when arranged between operations personnel. Operations Agreements describe this procedure.

From any of the WGS sites or the LGS, S-Band telemetry, which includes both real-time and playback data, is transferred in real-time to the MOC. All commands and S-Band telemetry are transmitted over a closed NISN-provided network. X-Band data received at the AGS/SGS are recorded then sent to the DHF. LGS transfers X-Band data received locally to the LPS in real-time or post-pass and plays back tapes from AGS/SGS to the LPS. Upon receipt at the ground stations, X- and S-Band data are processed differently due to their differing rates, purposes, and destinations. Details about data formats and transfer mechanisms for the telemetry interfaces follow the next paragraph, which describes S- and X-Band processing at the ground stations.

6.2.1.1 S-Band Telemetry Processing

S-Band telemetry received at LGS, WPS, SGS, or AGS are processed by a Programmable Telemetry Processor (PTP) following successful bit synchronization. The PTP provides frame synchronization, Reed-Solomon (R-S) decoding, data receipt time stamping, and IPDU header formulation/application. The telemetry data are also recorded at the receiving ground station so that retransmission is possible. This is described in paragraph 6.2.4. As described in paragraph 5.4.3.6, the incoming data stream consists of CCSDS-compliant CADUs. After successful processing at the ground station, the CADUs are prepended with IPDU headers and are sent to the MOC.

Real-time and SSR playback telemetry are maintained in separate data streams between the ground station and the MOC. Prior to each support, with the ground station acting as the server, the MOC initiates two independent TCP/IP sockets, one for each data stream. In the MOC, the real-time telemetry stream is used for clock correlation, spacecraft and ETM+ status assessment, and command verification. The playback telemetry is used primarily for on-going trend analysis and for troubleshooting, should problems arise. Most of these functions involve the extraction of information from successive protocol layers to recover spacecraft minor and major frame structures.

Clock correlation makes use of the spacecraft time code in the telemetry data and the PTP-supplied time stamp in the IPDU header. The MOC calculates the spacecraft clock's deviation from the station's reference time by subtracting the spacecraft clock value, transmission delay, and station equipment delay from the IPDU time stamp. Prior to launch, equipment delays are characterized at each station and provided to the MOC for the development of clock correlation functionality.

While S-Band data are being captured and processed, the PTP maintains processing status information. These statistics can be used locally to verify system status and can be reported to the MOC post-pass for use in trending and in problem isolation, should the need arise. This portion of the LGN-MOC interface is described in Section 6.6, along with other status and reporting mechanisms.

6.2.1.2 X-Band Telemetry Processing

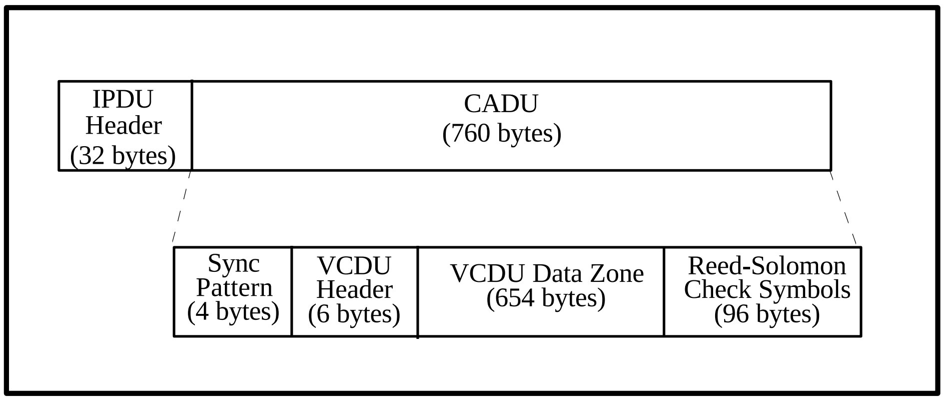
All X-band data recovered at the LGS and WGS are forwarded to the Landsat Processing System (LPS) for Level-Zero processing. Nominally, data recovered at the LGS are transferred to the LPS in real-time via dedicated serial data lines. X-band data received at the SGS and AGS are recorded on tapes so they can be sent to the DHF, where they are mounted on LGS recorders and replayed to the LPS.

The tapes created at the WGS sites contain digital recordings of the bit stream received from a specified X-Band link during Landsat 7 contacts. Tapes, along with supporting documentation, are shipped within 48 hours of data receipt. Details about the tape interface between the AGS/SGS and LGS are in paragraph 6.2.2.2.

6.2.2 Telemetry Formats

6.2.2.1 S-Band Telemetry Format

Landsat 7 S-Band telemetry is transmitted via TCP/IP from the LGS and WGS sites to the MOC as IPDUs, each containing a header and a CADU. Formats for the telemetry IPDU and its components are shown in Figure 6-2. The IPDU header, with Landsat 7 telemetry values is defined in Table 6-1. Test data, such as that used to perform pre-pass checkout, have the test flag set to “1” in the IPDU header.



860-4Landsat96/fig.12

Figure 6-2. Telemetry IPDU Format

6.2.2.2 X-Band Telemetry Format

Landsat 7 X-band data received at the AGS/SGS are recorded as a raw bit stream of CCSDS CADUs onto 19- millimeter wideband tapes. The LGS and WGS equipment was selected specifically to ensure compatibility among the facilities supporting Landsat 7. The bits recovered from the bit synchronizers are recorded in time-tagged, numbered blocks, allowing playbacks to start and stop at operator-specified tape locations. During periods in which the bit synchronizers do not detect data, their output is inhibited so that recording does not take place. This may occur, for example, prior to signal acquisition and during link outages. Each tape will contain either I- or Q-channel data recorded during one or more X-band supports.

Automated recording/tape handling units allow unattended operation of the AGS/SGS for up to 48 hours. The amount of data recorded per tape depends on the amount of data received at the site over a given interval. This, in turn, depends on the season, data requests, scene cloud cover, and other factors. Operations agreements and support plans contain details regarding tape capacity to be available to Landsat 7 over specified time intervals and shipping criteria (e.g. ship data 48 hours after recording, even if tape not full) for recorded tapes.

Table 6-1. Telemetry IPDU Header Values

Item No.	Field Name	Format & Size	Value	Use for Tlm
1	IPDU synchronization	unsigned integer (4 bytes)	74C2472C hex	x
2	IPDU length in bytes (everything from the start of IPDU sync field through the end of the IPDU)	unsigned integer (4 bytes)	788 decimal	x
3	Data type ID, consisting of:	(4 bytes total)		
3a	IPDU Source	unsigned integer (8 bits)	ID for source of IPDU (see Table C-2 for values)	x
3b	IPDU Destination	unsigned integer (8 bits)	01 (MOC) (from Table C-2)	x
3c	Message Type	unsigned integer (8 bits)	01 (r-t) 02 (pb) (from Table C-3)	x
3d	Spare	(8 bits)	0	
4	Header version number	unsigned integer (4 bits)	1	x
5	Data type	unsigned integer (4 bits)	0 (unused for L7)	
6	Message Time (GMT)	NASA PB-5 Code (Option C) (7 bytes)	(See Table C-4 for values)	x
7	Ground station physical port ID	unsigned integer (1 byte)	0 (unused for L7)	
8	Source VCDU sequence counter discontinuity	logical (1 bit)	0 = no source VCDU discontinuity 1 = source VCDU discontinuity detected	x
9	VCDU contains playback data	logical (1 bit)	0 = real-time telemetry 1 = playback telemetry	x
10	Recovery processing indicator	logical (1 bit)	0 = live from spacecraft 1 = playback from ground station	x
11	Test data indicator	logical (1 bit)	0 = operational data 1 = test data	x
12	CRC failure indicator	logical (1 bit)	0 (unused for L7)	
13	Path SDU source sequence counter discontinuity	logical (1 bit)	0 (unused for L7)	
14	Packet length error	logical (1 bit)	0 (unused for L7)	

Table 6-1. Telemetry IPDU Header Values (Cont'd)

Item No.	Field Name	Format & Size	Value	Use for Tlm
15	Packet fill indicator	logical (1 bit)	0 (unused for L7)	
16	Spare	(2 bits)	0	
17	Source VCDU ID, consisting of:	unsigned integer (14 bits total)		
17a	Spacecraft ID	unsigned integer (8 bits)	15 hex for L7	x
17b	Virtual Channel ID	unsigned integer (6 bits)	0 (All VCDUs for L7 telemetry have a VCID = 0)	x
18	Location of first octet of ground-generated fill data for a path SDU	unsigned integer (2 bytes)	0 (unused for L7)	
19	Spare	(4 bytes)	0	
20	Reed-Solomon error control flag	logical (1 bit)	0 = no errors or errors were corrected 1 = uncorrectable errors	x
21	Source VCDU header error decode results	unsigned integer (5 bits)	0 (unused for L7)	
22	Source VCDU error decode results	unsigned integer (10 bits)	This field is applicable only if the value of the Reed-Solomon error control flag = 0: 0 = no errors, If > 0, the number of corrected bits within the entire VCDU	x
	Total Header Length	32 bytes		

For identification purposes, each tape is assigned an ID number which is both recorded onto the tape and attached to the cartridge as a bar-coded sticker. To identify the tape's data contents, a tape log accompanies each tape sent from the AGS/SGS to the DHF. This file is described in paragraph 6.6.4, and the DHF response, the tape acknowledgment report, is described in paragraph 6.6.5.

6.2.3 Data Retention

The LGS and WGS sites retain copies Landsat 7 S-Band telemetry to serve as a back-up in case real-time transmission outages occur. These back-ups are kept for 72 hours unless the MOC or project personnel request longer retention on specific occasions. Upon request from the FOT to WGS operations personnel or to DHF staff, a replay will be scheduled for the requested data at a mutually acceptable time. For WGS sites, the FOT initiates retransmission scheduling with a phone call to WGS operations. An electronic-mail message with specifics to identify the data needing replay, such as AOS/LOS times, formalizes the request. For unmanned stations, retransmissions may have to occur during the next shift when personnel are available. Emergency situations will receive a higher priority and can be scheduled accordingly.

AGS/SGS will make duplicate copies of X-Band tapes and will retain the copies until notified that they are no longer needed. This notification process is described in paragraph 6.6.5. However, the FOT/MOC nominally attempt to schedule all high-priority data for recovery at LGS to reduce the risk of lost or damaged tapes.

6.2.4 Retransmission Rates

Retransmission rates for S-Band telemetry are based on the available bandwidth between the ground station and the MOC during the planned retransmission. The maximum rates supported for this interface are the same as for original transmissions, 4.864 Kbps for real-time telemetry and 256 Kbps for playback telemetry.

6.2.5 Data Quality

The data quality requirements for WGS support of Landsat 7 are given in the DMR, Section 2400. For the LGS, they are in DMR Section 2700.

6.3 Command Interface

6.3.1 General

The command data flow from the MOC to the ground stations is shown in Figure 6-1. Commands are transmitted as IPDUs to the PTP resident at the supporting site. The PTP strips the IPDU header from the CCSDS-formatted commands and transfers them to the uplink equipment chain. The MOC-to-ground station command format is described in paragraph 6.3.2. Following header checks and re-formatting, the sites throughput the command data stream to the spacecraft.

The command interface between the MOC and the ground stations is based on TCP/IP. Prior to each support, with the ground station acting as the server, the MOC initiates a socket connection for command data and another for command echoes. The PTP supports a command echo function that serves to verify data line and system configuration between the MOC and the ground station. When the MOC transmits a command IPDU, the PTP swaps the source and destination codes, updates the time field, and returns the command IPDU, now called a command echo, to the MOC. If the test flag in the IPDU header is set to "1," the PTP generates a command echo and returns it to the MOC but does not uplink the command data.

6.3.2 Command Format

Commands are sent by the ground stations to the spacecraft in the CCSDS CLTU format which is illustrated in Figure 6-3. The MOC and the ground stations use the IPDU format for inter-facility command transfer. This applies to test commands sent to the front end (e.g. PTP) at a ground station, the associated return of a command echo, and for "live" commands destined for the spacecraft. Table 6-2 lists its IPDU header values and Table 6-3 shows the structure of this format.

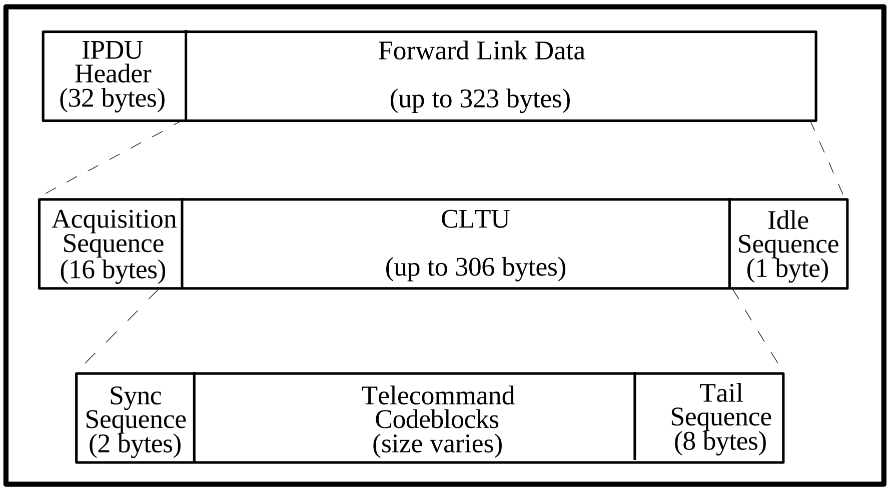


Figure 6-3. Command IPDU Format

6.4 Radiometric Data Interface

6.4.1 General

The MOC provides the requisite information for the ground stations to acquire Landsat 7. For the WGS sites, the data are sent to WOTIS, and from there, distributed to the ground station control systems. For the LGS, acquisition data are sent directly to the site. The MOC provides acquisition data files each day to ensure that acquisitions occur with only minimal delays. Each file contains 48 hours' worth of data to provide continuity between files and to mitigate any risk due to communications outages.

Exceptions to the acquisition data delivery schedule are the periods following orbital maneuvers. The MOC/FOT delivers normal no-maneuver products to the LGS and WGS. Following a successful maneuver, a second set of acquisition data are transmitted, reflecting the effects of the maneuver. Since acquisition data need to be updated rapidly, the FOT also sends a copy of the current daily schedule to WOTIS to trigger a database update at the WGS sites. The update ensures that the new acquisition data reaches the sites in the most expeditious manner. Section 6.4.2 provides more information on the data format used for WGS/LGS acquisition data.

Table 6-2. Command IPDU Values

Item No.	Field Name	Format & Size	Value	Use for Cmd
1	IPDU synchronization	unsigned integer (4 bytes)	74C2472C hex	x
2	IPDU length in bytes (everything from the start of IPDU sync field through the end of the IPDU)	unsigned integer (4 bytes)	up to 338 decimal	x
3	Data type ID, consisting of:	(4 bytes total)		
3a	IPDU Source	unsigned integer (8 bits)	01 (MOC) (from Table C-2)	x
3b	IPDU Destination	unsigned integer (8 bits)	ID for destination of IPDU (see Table C-2 for values)	x
3c	Message Type	unsigned integer (8 bits)	03 (command) 04 (echo) (from Table C-3)	x
3d	Spare	(8 bits)	0	
4	Header version number	unsigned integer (4 bits)	1	x
5	Data type	unsigned integer (4 bits)	0 (unused for L7)	
6	Message Time (GMT)	NASA PB-5 Code (Option C) (7 bytes)	(See Table C-4 for values)	x
7	Ground station physical port ID	unsigned integer (1 byte)	0 (unused for L7)	
8	Source VCDU sequence counter discontinuity	logical (1 bit)	0 = no source VCDU discontinuity 1 = source VCDU discontinuity detected	
9	VCDU contains playback data	logical (1 bit)	0 = real-time telemetry 1 = playback telemetry	
10	Recovery processing indicator	logical (1 bit)	0 = live from spacecraft 1 = playback from ground station	
11	Test data indicator	logical (1 bit)	0 = operational data 1 = test data (commands/echoes)	
12	CRC failure indicator	logical (1 bit)	0 (unused for L7)	
13	Path SDU source sequence counter discontinuity	logical (1 bit)	0 (unused for L7)	
14	Packet length error	logical (1 bit)	0 (unused for L7)	
15	Packet fill indicator	logical (1 bit)	0 (unused for L7)	
16	Spare	(2 bits)	0	
17	Source VCDU ID, consisting of:	unsigned integer (14 bits total)		

Table 6-2. Command IPDU Values (Cont'd)

Item No.	Field Name	Format & Size	Value	Use for Cmd
17a	Spacecraft ID	unsigned integer (8 bits)	15 hex for L7	x
17b	Virtual Channel ID	unsigned integer (6 bits)	All VCDUs for L7 telemetry have a VCID = 0	
18	Location of first octet of ground-generated fill data for a path SDU	unsigned integer (2 bytes)	0 (unused for L7)	
19	Spare	(4 bytes)	0	
20	Reed-Solomon error control flag	logical (1 bit)	0 = no errors or errors were corrected 1 = uncorrectable errors	
21	Source VCDU header error decode results	unsigned integer (5 bits)	0 (unused for L7)	
22	Source VCDU error decode results	unsigned integer (10 bits)	This field is applicable only if the value of the Reed-Solomon error control flag = 0: 0 = no errors, If > 0, the number of corrected bits within the entire VCDU	
	Total Header Length	32 bytes		

Table 6-3. Acquisition Data File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	EPHM	n/a
<project>	Mission identifier	L7	n/a
YYYY	Four-digit year identifier first day in file	1996	2100
MM	Two-digit month identifier	01	12
DD	Day of month identifier	01	31
V##	"V"ersion identifier, where ## is a two-digit counter	V00	V99

The LGS and WGS provide both one-way and two-way tracking support to Landsat 7. These data are generated during real-time support then transferred as a file post-pass to an FDF-supplied workstation in the MOC. The requirements for these services are defined in the DMR, Sections

2410 and 2710, for the WGS and LGS respectively. Section 6.4.3 identifies the formats used for the tracking data interface between the ground stations and the MOC.

6.4.2 Station Acquisition Data Format

The selected method for distributing acquisition data to the ground stations is a file containing an Improved Inter-Range Vector (IIRV) message. The format for this message is given in Appendix B of the Landsat 7-FDF ICD.

The naming convention for LGS files is defined in the Landsat 7 MOC-LGS ICD. For the WGS stations, the file naming convention is:

<type><project>YYYYMMDD.**V**##

where the definitions in Table 6-3 apply. As with file contents, the time in the file name is GMT-based.

An example of an acquisition data file name is: EPHML719980619.V00 to indicate that the file covers 19 June 1998 and is the first version (V00) to be sent to WOTIS from the MOC.

6.4.3 Metric Tracking Data Format

Tracking data are transferred from the LGS or WGS collection site to the MOC as files containing Universal Tracking Data Format (UTDF) records. The UTDF definition is in STDN 724, *Tracking and Acquisition Handbook for the Spaceflight Tracking and Data Network*. A single file is generated for each scheduled tracking data session and is FTP'd to the MOC within ten minutes of the end of the contact.

The spacecraft and vehicle identification codes needed for the UTDF header appear in Table 6-4.

Table 6-4. L7 UTDF Values

Name	SIC	VIC
L7	7368	01

The file naming convention, which uses GMT for time stamps, is:

<type><project>DOYHHMM.**V**DOYHHMM

where the definitions in Table 6-5 apply.

An example of a tracking data file name is: TRK_L70051845.V0051855 which indicates that the file contains tracking data collected during a period starting at day 005 at 18:45 GMT and that the file was prepared for transmission to the MOC 10 minutes later.

Table 6-5. Tracking Data File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	TRK_	n/a
<project>	Mission identifier	L7	n/a
DOY	Day of year of first data point in file	001	366
HH	Hours of day of first data point in file	00	23
MM	Minutes of hour of first data point in file	00	59
VDOY	"V"ersion identifier indicating day of year file was prepared for transmission	V001	V366
HH	Hours of day of file preparation time	00	23
MM	Minutes of hour of file preparation time	00	59

6.5 Scheduling Interface

6.5.1 General

Scheduling ground station support to meet Landsat 7 recovery needs is a responsibility of the FOT/MOC. The scheduling strategy maximizes LGS usage and fills coverage gaps with the WGS sites. The specifics regarding LGS scheduling, including file formats and naming conventions, are covered in the *Interface Control Document Between the Landsat 7 MOC and the LGS*. The process and specifics for WGS scheduling are covered in the remainder of this section.

Approximately three weeks before the interval being scheduled, the scheduling process begins with the FOT/MOC sending a request file to WOTIS. The request file, which follows the same format used in all MOC-WOTIS schedule exchanges, is based on a general file containing view information for all Landsat 7 ground stations. The views for the WGS sites are filtered by the MOC and FOT based on several criteria, including coverage availability at the LGS and pass duration. These resulting views represent a more accurate prediction of actual Landsat 7 support needs and, therefore, are sent to WOTIS as the first step in the scheduling process. Once WOTIS receives the file, a preliminary schedule is generated based on the Landsat 7's views and the support requirements of other WGS-supported spacecraft.

This forecast schedule file, which is FTP'd to the MOC approximately 2.5 weeks before the target week, contains entries for each request that WGS resources can support. The entry types are based on defaults which represent the most common Landsat 7 support configurations. Based on agreements between WGS and the Landsat 7 project, support entries for both X-Band and S-

Band are generated for SGS and AGS since two RF equipment chains are used. For WPS contacts, only S-Band support is required so only a single entry appears in the schedule. The WOTIS scheduling system generates tags that are used to uniquely identify each X-Band and each S-Band support in a schedule. Any subsequent actions relevant to a given support by either the MOC/FOT or WGS make use of this tag.

Between one week and two weeks before the target week, the MOC/FOT returns a confirmed schedule to WOTIS in response to the forecast schedule. This schedule further refines the support that Landsat 7 needs from WGS by containing only the X-Band and S-Band entries that are required to meet mission objectives. This schedule is expected to contain a subset of the coverage that was originally listed in the strawman request file initially sent to WOTIS. Entries that were in the forecast schedule but do not appear in the confirmed schedule are effectively deleted. In addition to deleting contacts, the MOC/FOT can make any necessary changes to the support entries via the confirmed schedule. For example, specific on and off times for S-Band station resources can be given by adjusting the times associated with the contact and tracking support can be changed from one-way to two-way or vice versa.

Each day, the MOC/FOT sends a daily schedule file to WOTIS by 2000z. The file begins with the first support starting after 0000z and covers a 48-hour period. This schedule is based on the same format used for the other schedule files. The parameters that will be given at this time are X-Band frequency (i.e. which of Landsat 7's three will be in use) and specific equipment on/off times. As with the other transmissions, FTP provides acknowledgment that the daily schedule arrived successfully at WOTIS. The transfer of the daily schedule is the final electronic exchange in the scheduling process. Any modifications after this point, including requests for emergency support, are accomplished via voice coordination between the FOT and WGS operations staff, with confirmation via electronic mail.

6.5.2 Support Requirements

Support requirements for each network and ground station providing coverage for Landsat 7 are located in the *Landsat 7 Detailed Mission Requirements (DMR)*. The LGS and WGS are considered the primary S- and X-Band communications facilities for the mission. Since it is a dedicated facility, LGS coverage is maximized during the weekly scheduling process.

WGS usage is a function of both orbital geometry and science data requests. Tracking data acquisition requirements are also a consideration in determining station coverage needs. An accurate orbit solution is predicated on sufficient tracking data collection at various geographic locations. MOC/FOT scheduling determines specific WGS support based on these factors and on the amount of downlink time available at LGS. WPS provides S-Band support only while AGS and SGS provide S- and X-Band capabilities. The strawman request file that the MOC/FOT sends to WOTIS contains a best-guess estimate of support needs for the target week based on long-term science plans and LGS visibility. The strawman will contain more than the essential contact times to give WOTIS some flexibility in meeting Landsat 7 needs in conjunction with those of other users. Once WOTIS responds with a forecast schedule, the FOT can eliminate any unnecessary supports by not including them in the confirmed schedule returned to WOTIS. If the forecast schedule contains insufficient WGS support, operator negotiation via voice and/or electronic mail is required.

Based on resource loading studies conducted prior to launch, WGS support is expected to total approximately seven passes per day. Four passes are projected for AGS daily, with and average length of 9.6 minutes each. These passes are likely to be centered around 0000z. The SGS is expected to take one or two ten-minute passes per day, probably near 1200z. WPS may be scheduled once per day depending on command and S-Band telemetry needs. This is most likely to occur in either the very early or late hours of the GMT day.

6.5.3 Schedule File/Data Formats

This section gives the file formats and naming conventions for the data exchanged between WOTIS and the MOC. The FTP addresses for all of the files listed in this section and necessary account and password information are exchanged by representatives of each facility prior to launch and during the mission as necessary. Operations agreements between the FOT and WGS staff identify these representatives and provide the details for communicating this information in a safe, effective manner. All schedule file transfers between the MOC and WOTIS make use of a gateway mechanism to maintain security since WOTIS is on an "open" network.

6.5.3.1 Strawman Request File Format

The strawman request file uses the Request/Response Format given in Appendix D. Records are included for each requested S-Band and X-Band contact. The tag field in each record is set to zero by the MOC since this value is assigned by WOTIS later in the scheduling process. The X-Band designator is also a default value since the actual frequency is unknown until ETM+ imaging is planned. The period to be scheduled is Monday, 0000z, through Sunday, 23:59:59z. However, the file covers one week plus a day of overlap on each end to allow continuity from one scheduling period to the next. Thus, each file starts at the first request after 0000z on the Sunday of the target week and ends with the last LOS eight days later (i.e. a Monday). Supports that start in one week and end in the next (e.g. Sunday 23:55:00 to Monday 00:05:00) are requested and scheduled as part of the earlier week. Due to the overlap included in each file, such supports are listed in both weeks' files.

The following naming convention is used for the WGS strawman request file:

<type><project>WK##.**V**##

where the definitions in Table 6-6 apply.

An example of a request file name is: REQ_L701.V00 to indicate that the file includes 1 January and is the first version the MOC has sent to WOTIS.

Table 6-6. Strawman Request File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	REQ_	n/a
<project>	Mission identifier	L7	n/a
WK##	Week number, two digits	01[1]	53[2]
V##	"V"ersion identifier, where ## is a two-digit counter	V00	V99

[1] Week 1 is defined as the week containing 1 January.

[2] Some years will contain 52 weeks then roll over to Week 01 while others will roll over after Week 53. This occurs because each week runs from Monday through Sunday and Week 01 may contain the end of December.

6.5.3.2 Forecast Schedule Format

The forecast schedule is FTP'd from WOTIS to the MOC on the Thursday which is 2.5 weeks before the first day of the week being scheduled. Like the strawman request file, the forecast file covers one Monday-through-Sunday scheduling week and runs from Sunday through Monday to provide overlap. This file contains two Request/Response Format records for each available AGS and SGS contact, one for S-Band and one for X-Band. WPS supports are represented by an S-Band record only. The Request/Response Format record format is given in Appendix D.

The filename for the forecast schedule follows this format:

<type><project>WK##.**V**DOYHHMM

where the name segments follow the definitions in Table 6-7.

An example of a forecast schedule file name is: RES_L701.V3531712 which indicates that the file includes 1 January and was assembled for transmission on day 353 at 17:12z.

6.5.3.3 Confirmed Schedule Format

The confirmed schedule covers the same time period as the forecast schedule. That is, it runs from Sunday through Monday. It contains a data- and requirements-driven list of events that Landsat 7 requires of the WGS sites, and is a subset of the contacts in the forecast schedule. Each event again is formatted as a Request/Response Format record, defined in Appendix D.

The naming convention for the confirmed schedule is:

<type><project>WK##.**V**##

where the definitions in Table 6-8 apply.

Table 6-7. Forecast Schedule File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	RES_	n/a
<project>	Mission identifier	L7	n/a
WK##	Week number	01[1]	53[2]
VDOY	"V"ersion identifier indicating day of year file was prepared for transmission	V001	V366
HH	Hours of day of file preparation time	00	23
MM	Minutes of hour of file preparation time	00	59

1 Week 1 is defined as the week containing 1 January.

2 Some years will contain 52 weeks then roll over to Week 01 while others will roll over after Week 53. This occurs because each scheduling week runs from Monday through Sunday and if 1 January occurs on Week 01 may contain the end of December.

Table 6-8. Confirmed Schedule File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	REQU	n/a
<project>	Mission identifier	L7	n/a
WK##	Week number	01[1]	53[2]
V##	"V"ersion identifier, where ## is a two-digit counter	V00	V99

[1] Week 1 is defined as the week containing 1 January.

[2] Some years will contain 52 weeks then roll over to Week 01 while others will roll over after Week 53. This occurs because each week runs from Monday through Sunday and Week 01 may contain the end of December.

An example of a possible file name for the confirmed schedule is:

REQUL701.V01, for a file containing 1 January and is the second version of the confirmed schedule sent from the MOC to WOTIS.

6.5.3.4 Daily Schedule Format

The daily schedule file covers a single day plus the following day for overlap and is transferred to WOTIS at least four hours before each day begins. Even though only X-Band supports may contain updates, the daily schedule file will include all supports at the WGS sites. The file is routinely used to specify actual X-Band frequencies that will be in use during X-Band events since the actual may differ from the default frequency used in the previous schedule files. The normal FOT/MOC procedure is to FTP the daily schedule as a matter of course, so that the update occurs even if no values are changed. Since only certain values are modifiable in the daily schedule, the FOT/MOC accomplishes other types of changes, such as support addition, via voice coordination with WGS operations personnel. This type of schedule file may also be used to trigger a database update at WOTIS, which in turn automatically updates the information at the ground stations. This allows the FOT to supply updated acquisition data for distribution to the sites without operator intervention by WGS personnel. This capability may be used around maneuver periods when updated tracking data may be needed. The daily schedule is based on the Request/Response Format record format, defined in Appendix D.

The filename for the daily schedule follows this format:

<type><project>DOY.**V**##

where the definitions in Table 6-9 apply.

Table 6-9. Daily Schedule File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	REQF	n/a
<project>	Mission identifier	L7	n/a
DOY	Day of year covered by this schedule	001	366
V##	"V"ersion identifier, where ## is a two-digit counter	V00	V99

An example of a daily schedule file name is: REQFL7002.V00, indicating that the daily schedule is for 2 January and is the first version to be sent from the MOC to WOTIS.

6.6 Status Data and Report Interfaces

6.6.1 General

Both the WGS and LGS provide status information to the FOT/MOC electronically. The LGS provides post-pass contact status reporting and problem reporting. Descriptions of this interface, along with data content and format, are located in the MOC-LGS ICD. The WGS provides real-time contact status reporting and post-pass summary reporting. In addition to these electronic methods, voice communication takes place as necessary. Requirements for the LGN to provide status information are in the DMR, with Section 2700 containing LGS requirements and Section

2400 containing WGS requirements. Since the LGS reporting interfaces are covered in a separate document, WGS real-time status reporting, summary reporting, and problem reporting are covered in sections 6.6.2, 6.6.3, and 6.6.4 respectively. The DHF provides reports on the receipt of and data recovery from X-Band tapes. This interface is covered in Section 6.6.5.

6.6.2 Real-time Status

For X- and S-band data, RF equipment status information is provided by the WGS sites. For S-band data, additional information is provided by the front end at the supporting station. Real-time status data sent by WGS sites arrives at the MOC via TCP/IP and is routed to an International Business Machines-compatible Personal Computer (IBM PC). SPOD-provided software runs on the PC to receive and display the status data. The data are also written to a file so they may be stored for subsequent review or analysis by the FOT. The total data rate for this stream is TBD Kbps.

6.6.2.1 WGS Real-time Status Data Description

Since the status information sent by the WGS sites is displayed by WGS-provided software, the format specification is not necessary for this ICD. Data contents, which were arranged between the FOT and WGS personnel, are part of the interface agreement, and therefore, are listed below:

a. Antenna azimuth and elevation angles

b. Tracking control mode (program track, autotrack)

c. Transmitter mode (antenna or dummy load)

d. Exciter mode (carrier modulation status)

e. Exciter/receiver coherency

f. Receiver automatic gain control level (S- and X-Bands)

g. Demodulator lock status (S- and X-Bands)

h. Bit synchronization status (S- and X-Bands)

6.6.3 WGS Downlink Summary Report

Following every support taken at a WGS site, statistics are collected from various hardware and software station components. These data are transmitted to WOTIS, where they are stored and used in the generation of a downlink summary report which is subsequently transferred to the MOC and to the DHF. This report is an ASCII file designed to be viewed with standard text editing tools. WOTIS-DHF transfers occur over open network connections. WOTIS-MOC connections make use of a gateway to preserve security.

The format for the report is given in Appendix E. The naming convention is: <type><project>DOYHH.VDOYHHMM, where the definitions in Table 6-10 are applicable.

Table 6-10. Downlink Summary Report File Name Definition

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	DNL_	n/a
<project>	Mission identifier	L7	n/a
DOY	Day-of-year of contact start	001	366
HH	Hour of day of contact start	00	23
VDOY	"V"ersion identifier indicating day of year file was prepared for transmission	V001	V366
HH	Hours of day of file preparation time	00	23
MM	Minutes of hour of file preparation time	00	59

An example of a downlink summary report name is DNL_L716723.V1680012, indicating that it is for a pass that began during the 23rd hour of day 167 and was prepared for transmission on day 168 at 00:12z.

6.6.4 Tape Shipment Report

When tapes containing X-Band data are shipped from the AGS and SGS to the DHF, a report is sent electronically to notify the DHF that the tape(s) are en route and can be expected within the normal shipping time of a few days. This report is sent via open networks.

The format for this report is given in Appendix F. the naming convention is: <type><project>YYYYDOY.**V**DOYHHMM where the definition in Table 6-11 apply.

Table 6-11. Tape Shipment Report Naming Convention

Filename Segment	Definition	Range	
		Minimum	Maximum
<type>	File type	TSR_	n/a
<project>	Mission identifier	L7	n/a
YYYY	Year of Shipment	1996	2100
DOY	Day of year of shipment	001	366
VDOY	"V"ersion identifier indicating day of year file was prepared for transmission	V001	V366
HH	Hours of day of file preparation time	00	23
MM	Minutes of hour of file preparation time	00	59

An example of a possible file name is TSR_L72001327.V3271519, for a type shipment report that was shipped on day 327 of year 2001, after having been generated at 15:19z.

6.6.5 Tape Acknowledgment Report

After tapes are received at the DHF, they are played back from the LGS to the LPS. If any problems are encountered, the DHF reports this and receives a back-up copy of the data. If no trouble occurs during data recovery, the DHF reports this and the originating ground station can re-use tapes containing back-up copies of the data. DHF transfers tape acknowledgment reports to WOTIS using FTP over open networks. The directory structure, account name, and password information are contained in operations agreements between the DHF and WGS.

The naming convention for tape acknowledgment report is:

<type><project>TAPELABEL.RYYYYDOY where definitions in Table 6-12 apply.

Table 6-12. Tape Acknowledgment Report File Name Definition

Filename Segment	Definition	Range	
		Minimum	**Maximum**
<type>	File type	EDC_	n/a
<project>	Mission identifier	L7	n/a
TAPELABEL	Volume label of tape	n/a (12-character ID assigned to each tape at its originating site)	n/a
R	Results of ingest	"1"if all good	"0"if one or more problems (i.e., details below)
YYYY	Year of receipt at EDC	1996	2100
DOY	Day of year of receipt	001	366

An example of a possible tape acknowledgment report name is: EDC_L7SGSAPX123456.11998305, for a suggesful ingest of tape number SGSAPX123456 on day 305 of 1998.

The format for the report is given in Appendix F.

Appendix A. RF Link Calculations

A1. L7 to LGS/AGS/SGS X-Band Link Calculations

A2. L7 to LGS/AGS/SGS/WPS S-Band Link Calculations

The receivers used in the LGS/AGS/SGS/ WPS do not utilize a carrier loop filter for acquisition. The actual bandwidth is the IF bandwidth of the receiver.

The carrier loop noise bandwidth 12 MHz used in the link calculation is the IF bandwidth

Appendix B. Antenna Coverage

This appendix contains the antenna coverage patterns for the L7 Satellite S-Band omni antennas and the X-Band antenna transmit pattern The antenna coverage patterns currently provided are based on performance measurements on the ground using similar antennas from other spacecraft which are representative of the predicted L7 performance. The antenna coverage patterns will be updated as better predictions of L7 Satellite antenna performance become available.

B1. S-Band Antenna Receive Patterns

B2. S-Band Antenna Transmit Patterns

B3. X-Band Antenna Transmit Patterns

Figure B-1. Receive Antenna Patterns from L7 Zenith Mounted/Nadir Mounted Omni Antennas

Figure B-2. Transmit Antenna Patterns L7 Zenith Mounted Omni Antenna

Figure B-3. L7 GXA Transmit Directivity Pattern

Appendix C. IPDU Header Summary

Table C-1 below gives the complete IPDU header structure. The three “Use for” columns indicate which header entries are meaningful for each of the three IPDU data types. The header is fixed at 32 bytes with unused fields being set to zero.

Table C-1. IPDU Header Structure

Item No.	Field Name	Format & Size	Value	Use for Tlm	Use for Cmd
1	IPDU synchronization	unsigned integer (4 bytes)	74C2472C hex	x	x
2	IPDU length in bytes (everything from the start of IPDU sync field through the end of the IPDU)	unsigned integer (4 bytes)		x	x
3	Data type ID, consisting of:	(4 bytes total)			
3a	IPDU Source	unsigned integer (8 bits)	ID for source of IPDU (see Table C-2 for values)	x	x
3b	IPDU Destination	unsigned integer (8 bits)	ID for destination of IPDU (see Table C-2 for values)	x	x
3c	Message Type	unsigned integer (8 bits)	(see Table C-3 for values)	x	x
3d	Spare	(8 bits)	0		
4	Header version number	unsigned integer (4 bits)	1	x	x
5	Data type	unsigned integer (4 bits)	0 (unused for L7)		
6	Message Time (GMT)	NASA PB-5 Code (Option C) (7 bytes)	(See Table C-4 for values)	x	x
7	Ground station physical port ID	unsigned integer (1 byte)	0 (unused for L7)		

Table C-1. IPDU Header Structure (Cont'd)

Item No.	Field Name	Format & Size	Value	Use for Tlm	Use for Cmd
8	Source VCDU sequence counter discontinuity	logical (1 bit)	0 = no source VCDU discontinuity 1 = source VCDU discontinuity detected	x	
9	VCDU contains playback data	logical (1 bit)	0 = real-time telemetry 1 = playback telemetry	x	
10	Recovery processing indicator	logical (1 bit)	0 = live from spacecraft 1 = playback from ground station	x	
11	Test data indicator	logical (1 bit)	0 = operational data 1 = test data	x	x
12	CRC failure indicator	logical (1 bit)	0 (unused for L7)		
13	Path SDU source sequence counter discontinuity	logical (1 bit)	0 (unused for L7)		
14	Packet length error	logical (1 bit)	0 (unused for L7)		
15	Packet fill indicator	logical (1 bit)	0 (unused for L7)		
16	Spare	(2 bits)	0		
17	Source VCDU ID, consisting of:	unsigned integer (14 bits total)			
17a	Spacecraft ID	unsigned integer (8 bits)	15 hex for L7	x	x
17b	Virtual Channel ID	unsigned integer (6 bits)	All VCDUs for L7 telemetry have a VCID = 0	x	
18	Location of first octet of ground-generated fill data for a path SDU	unsigned integer (2 bytes)	0 (unused for L7)		
19	Spare	(4 bytes)	0		
20	Reed-Solomon error control flag	logical (1 bit)	0 = no errors or errors were corrected 1 = uncorrectable errors	x	
21	Source VCDU header error decode results	unsigned integer (5 bits)	0 (unused for L7)		
22	Source VCDU error decode results	unsigned integer (10 bits)	This field is applicable only if the value of the Reed-Solomon error control flag = 0: 0 = no errors, If > 0, the number of corrected bits within the entire VCDU	x	
	Total Header Length	**32 bytes**			

Table C-2. Landsat 7 IPDU Source and Destination Codes

Source/Destination Name	Integer Code (1 byte, hexadecimal)	ASCII Station Designator
Landsat 7 MOC Greenbelt, MD	01	L7M
LGS, S-Band/Generic Sioux Falls, SD	02	LGS
EOS-Alaska, S-Band/Generic Poker Flats, AK	03	AGS
EOS-Svalbard, S-Band/Generic Spitzbergen, Norway	04	SGS
SN-White Sands Complex Las Cruces, NM	05	WSC
Weilheim, Germany	06	WIL
Lockheed Martin Missiles and Space Valley Forge, PA	07	VLF
Vandenburg AFB, CA	08	VAF
Wallops Orbital Tracking Station Wallops Island, VA	60	WPS

Table C-3. L7 IPDU Data Types

Message Type	Corresponding Integer Code (8 bits) (hex)
Narrowband real-time telemetry	01
Narrowband spacecraft recorder telemetry	02
Command data message	03
Command echo message	04

Table C-4. NASA PB-5 Time Code Format (Option C)

Item No.	Field Name	Format & Size	Value
1	Flag bit	logical (1 bit)	1
2	Truncated Julian Day	unsigned integer (14 bits)	Truncate the most significant decimal digits, retaining only the four least significant ranging from 0 to 9999. The current Julian day epoch begins at midnight 1995, October 9, 10. October 10, 1995 is day 0.
3	Seconds of Day	unsigned integer (17 bits)	range = 0 to 86399
4	Milliseconds of Seconds	unsigned integer (10 bits)	range = 0 to 999
5	Microseconds of a Millisecond	unsigned integer (10 bits)	range = 0 to 999
6	Spare	(4 bits)	
	Total Length	**7 bytes**	

Appendix D. Request/Response Record Formats

This appendix contains a description of the Request/Response format used in schedule files exchanged between the MOC and WOTIS. The record length varies, up to a maximum of 62 ASCII characters, including the record terminator, which is a single linefeed (ASCII 10_{10}) character. Fields within a record are always separated by commas (ASCII 44_{10}), even when fields are not used (e.g., the Tag field). The example records in Figure D-1 illustrate the Request/Response format.

Table D-1. Request/Response Record Format

Item No.	Name	Format	Max Size (bytes)	Value(s)
1	Tag	ASCII	15	Empty[1] (strawman) or ID number assigned by WOTIS
2	Project	ASCII	2	"L7"
3	Facility	ASCII	3	one of the following: • "AGS" • "SGS" • "WPS"
4	Beginning of Track	GMT Field[2]	13	station equipment "on" time
5	End of Track	GMT Field[2]	13	station equipment "off" time
6	Activity Code	ASCII	3	empty (if X-Band) or one value from Table D-3
7	Orbit	ASCII	10	value from MOC planning aids
8	Band	ASCII	2	one of the following: • "X0" = delete request[3] • "X1" = 8082.5 MHz • "X2" = 8212.5 MHz • "X3" = 8342.5 Mhz • "S1" = S-Band

1. This field is empty in the strawman request file that the MOC sends to WOTIS. For all other schedule files, a WOTIS-generated identification number is used.

2. See Table D-2 for format.

3. The value "X0" in this field indicates that the contact should be deleted from the schedule.

Table D-2. GMT Field Definition

Field: yyyydddhhmmss		Format (Size): ASCII (13 bytes)	Range
yyyy	Year	ASCII (4 bytes)	1996 through 2100
ddd	Day of Year	ASCII (3 bytes)	001 through 366
hh	Hour	ASCII (2 bytes)	00 through 23
mm	Minute	ASCII (2 bytes)	00 through 59
ss	Second	ASCII (2 bytes)	00 through 59

Table D-3. Landsat 7 WGS Activity Codes

Activity Code	Receive/ Record	Command	Tracking Data/ Mode	Data Forwarding
TR1	4.864 Kbps 256 Kbps	2 Kbps	2-Way/ Coherent	4.864 Kbps 256 Kbps
TR2	1.216 Kbps 256 Kbps	2 Kbps	2-Way/ Coherent	1.216 Kbps 256 Kbps
TR3	4.864 Kbps 256 Kbps	2 Kbps	1-Way/ Non-coherent	4.864 Kbps 256 Kbps
TR4	1.216 Kbps 256 Kbps	2 Kbps	1-Way/ Non-coherent	1.216 Kbps 256 Kbps
PBK	256 Kbps		None/ Non-coherent	256 Kbps
SPC[1]				

1. SPC is used for testing and other special activities. Configuration will be arranged by the FOT and WGS personnel and documented in briefing messages as needed.

Figure D-1. Request/Response Record Examples

```
,L7,AGS,1999149135500,1999149140500,TR1,3056,S1<linefeed>
,L7,AGS,1999149135500,1999149140500,,3056,X1<linefeed>
W9821-1,L7,AGS,1999149135500,1999149140500,TR1,3056,S1<linefeed>
W9821-2,L7,AGS,1999149135500,1999149140500,,3056,X1<linefeed>
```

Appendix E. Downlink Summary Report Format

This appendix contains the format for the Downlink Summary Report. Each file consists of one or more records. Fields within a record (Items) are separated by a single comma (ASCII 44_{10}) and records are delimited by a linefeed (ASCII 10_{10}) character. Table E-1 lists the contents of each record.

Table E-1. Downlink Summary Report Record Format

Item No.	Name	Format	Max Size (bytes)	Meaning/Value(s)
1	Tag	ASCII	15	Support identifier assigned by WOTIS
2	Satellite	ASCII	15	"L7"
3	Ground Station	ASCII	10	Ground station receiving data
4	Operation	ASCII	8	"Support" or "Playback"
5	Tape #	ASCII	10	Volume label of tape[1]
6	Start Address	ASCII	10	Position on tape where support began
7	End Address	ASCII	10	Position on tape where support ended
8	Start Time	GMT Field[2]	13	Time when tape began to record
9	End Time	GMT Field[2]	13	Time when recorder stopped recording
10	Orbit	ASCII	10	S/C orbit number
11	Recorder ID	ASCII	10	Identifying number of recorder
12	Bit Sync Start	GMT Field[2]	13	Time when bit sync & demod both achieved lock status
13	Bit Sync Stop	GMT Field[2]	13	Time when bit sync & demod both lost lock status
14	Acquisition Status	unsigned fixed decimal percent	6	% of time bit sync and demod were both in lock status within customer support request
15	Recorded	ASCII	1	Indicates if support was recorded on tape, One of the following: • "Y" • "N"
16	Tracked	ASCII	1	Indicates if antenna system tracked S/C, One of the following: • "Y" • "N"

Table E-1. Downlink Summary Report Record Format (Cont'd)

Item No.	Name	Format	Max Size (bytes)	Meaning/Value(s)
17	Antenna Statistics	TBD	TBD	TBD
18	PTP Frame Statistics	TBD	TBD	TBD
19	Recorder Node Statistics	TBD	TBD	TBD
20	Comments	ASCII	60	WGS comments relative to reported support
1. If a back-up tape was used, there will be two records with the same Tag #, one for each tape used. 2. Refer to GMT Time Format in Request/Response section above.				

Appendix F. Tape Exchange File Formats

This appendix contains the formats for the Tape Shipment Report and the Tape Acknowledgment Report. Each file consists of one or more records. Fields within a record (Items) are separated by a single comma (ASCII 44_{10}) and records are delimited by a linefeed (ASCII 10_{10}) character. Tables F-1 and F-2 define the record formats for these files.

Table F-1. Tape Shipment Report Record Format

Item No.	Name	Format	Max Size (bytes)	Meaning/Value(s)
1	Tag	ASCII	15	Support identifier assigned by WOTIS
2	Satellite	ASCII	15	“L7”
3	Ground Station	ASCII	10	Ground station receiving data
4	Type of Operation	ASCII	3	One of the following: • “SUP”= real-time support • “TST”= test • “BEX”= bit-error rate test
5	Conveyance	ASCII	10	Identifier for box in which tapes were shipped
5	Tape #	ASCII	12	Volume label of tape[1]
6	Start Address	ASCII	10	Position on tape where support began
7	End Address	ASCII	10	Position on tape where support ended
8	Start Time	GMT Field[2]	13	Time when tape began to record
9	End Time	GMT Field[2]	13	Time when recorder stopped recording
10	Orbit	ASCII	10	S/C orbit number
20	Comments	ASCII	60	WGS comments relative to reported support

1. This may be either the prime or back-up tape recorded during support; includes site identifier.
2. Refer to GMT Time Format in Table D-2.

Table F-2. Tape Acknowledgment Report Record Format

Item No.	Name	Format	Max Size (bytes)	Meaning/Value(s)
1	Tag	ASCII	15	Support ID previously assigned by WOTIS
2	Tape #	ASCII	12	Volume Label of Tape
3	Date Received	GMT Field[1]	13	Date received at EDC
4	Date Ingested	GMT Field[1]	13	Date tape ingested (Julian): 1-366
5	Ingest Results	ASCII	1	Logical, one of the following: "1"=successful, good "0"=unsuccessful, need backup
6	Failure Report Reference	ASCII	8	Reference to EDC Problem Report #
7	Comments	ASCII	60	EDC Comments (if any)
1. Refer to GMT Time Format in Table D-2.				

Abbreviations and Acronyms

AGC	Automatic Gain Control
AGS	Alaska Ground Station
AM	Amplitude Modulation
AOS	Acquisition of Signal
AOS	Advanced Orbiting Systems
AQPSK	Asynchronous Quadrature Phase Shift Keying
ASCII	American Standard Code for Information Interchance
BCH	Bose-Chaudhuri-Hocquenghem
BER	Bit Error Rate
biφ-S	Biphase-S
BOT	Beginning of Track
BPDU	Bitstream Protocol Data Unit
bps	Bits per Second
BSU	Baseband Switching Unit
BW	bandwidth
C	Celcius
C&DH	Command and Data Handling
C&T	Command and Telemetry
CADU	Channel Access Data Unit
CCSDS	Consultative Committee for Space Data Systems
CIC	Command Interrupt Code
CLASS	Communications Link Analysis Simulation System
CLTU	Command Link Transmission Unit
CNR	Carrier to Noise Ratio
CRC	Cyclic Redundancy Check
CVCDU	Coded Virtual Channel Data Unit
CW	Continuous Wave
DAAC	Distributed Active Archive Center

DB	Data Block
dB	decibel
dB-K	Decibel/degrees Kelvin
dBi	Decibel Input
dBM	Decibel relative to 1 milliWatt
dBW	Decibel relative to 1 Watt
DHF	Data Handling Facility
DMR	Detailed Mission Requirements
DMS	Doppler Measurement System
E_bNo	Energy per bit to Noise Ratio
EDAC	Error Detection and Correction
EDC	EROS Data Center
EIRP	Effective Isotropic Radiated Power
El	Elevation
EOT	End of Track
EROS	Earth Resources Observation System
ETM+	Enhanced Thematic Mapper Plus
FDF	Flight Dynamics Facility
FTP	File Transfer Protocol
G/T	Gain as a function of Temperature
GDE	Gimbal Drive Electronics
GMT	Greenwich Mean Time
GRO	Gamma Ray Observatory
GSFC	Goddard Spaceflight Center
GXA	Gimballed X-Band Antenna
Hz	Hertz
I	In-phase
ICD	Interface Control Document
IF	Intermediate Frequency
IF	Interface
IGS	International Ground Station
IIRV	Improved Inter-Range Vector

IP	Internet Protocol
IPDU	Internet Protocol Data Unit
Kbps	Kilobits per Second
KHz	Kilohertz
km	kilometer
L7	Landsat 7
LGS	Landsat 7 Ground Station
LHC	Left-hand Circular
LHCP	Left-hnd Circularly Polarized
LPO	Landsat Project Office
LPS	Landsat Processing System
Mbps	Megabits per Second
MHz	Megahertz
mm	Millimeter
MMO	Mission Management Office
MO&DSD	Mission Operations and Data Systems Directorate
MOC	Mission Operations Center
NASA	National Aeronautics and Space Administration
NISN	NASA Integrated Service Network
NRZ-L	Non-Return to Zero-Level
NRZ-M	Non-Return to Zero-Mark
PCD	Payload Correction Data
PCM	Pulse Code Modulation
PL-DRO	Phase-Locked Dielectric Resonator Oscillator
PLF	Payload Fairing
PM	Phase Modulation
PN	Pseudorandom
ppm	Parts per Million
PSK	Phase Shift Keying
PTP	Programmable Telemetry Processor
Q	Quadrature
QPSK	Quadrature Phase Shift Keying

R-S	Reed-Solomon
RF	Radio Frequency
RHC	Right-hand Circular
RHCP	Right-Hand Circularly Polarized
RMS	Root Mean Square
RS	Reed-Solomon
SBT	S-Band Transponder
SCC	Spacecraft Command Counter
SCID	Spacecraft Identifier
SDU	Source Data Unit
SGS	Svalbard Ground Station
SN	Space Network
SNR	Signal to Noise Ratio
SPOD	Suborbital Projects and Operations Directorate
SSPA	Solid State Power Amplifier
SSR	Solid State Recorder
STDN	Spaceflight Tracking and Data Network
TCP	Transmission Control Protocol
TCXO	Temperature Compensated Crystal Oscillator
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
U/L	Uplink
UTDF	Universal Tracking Data Format
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identifier
WFF	Wallops Flight Facility
WGS	Wallops Ground System
WOTIS	Wallops Orbital Tracking Information System
WOTS	Wallops Orbital Tracking Station
WPS	Wallops Orbital Tracking Station